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THE PLANT DISEASE REPORTER

Issued By

THE PLANT DISEASE SURVEY

Division of Mycology and Disease Survey

BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

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SUPPLEMENT 191

PLANT PATHOLOGICAL INVESTIGATION
IN THE UNITED STATES

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The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Division of Mycology and Disease Survey serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

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THE PLANT DISEASE SURVEY DIVISION OF MYCOLOGY AND DISEASE SURVEY

Plant Industry Station

Beltsville, Maryland

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FOREWORD

Paul R. Miller

One of the objectives of the Plant Disease Survey is to supply plant pathologists with geographical and historical backgrounds to the problems confronting them. This can only be accomplished with the cooperation of plant pathologists themselves. The series of Supplements to the Plant Disease Reporter, of which this is the first, presenting articles on the broad topic of plant disease investigations in this country, is the result of such cooperation in a project more extensive than most of those suggested by the Survey.

The series was planned to bring out the diversity of plant disease problems in the United States and to show how the results of plant pathological investigation have affected plant disease occurrence and importance, both now and in the past; possibly, furthermore, to indicate the probable effect of present knowledge and action on the types of plant disease situations arising in the future and on methods of handling them. The middle of the century is traditionally a time for review and prediction; moreover, the past several years have seen so much change in problems and attitudes, and such great advance in control, that 1950 may well mark a turning point for historians of plant pathology in time to come.

Pathologists who are taking part in present studies, or who have seen the results of past investigation in their own regions, are best fitted to select and evaluate material for this purpose. Therefore, the Survey asked the help of its State collaborators, who constitute an official part of its organization, and of pathologists in the Bureau of Plant Industry, Soils, and Agricultural Engineering to which the Survey belongs, and in the domestic and foreign plant disease quarantine services in the Bureau of Entomology and Plant Quarantine.

This Supplement contains articles received by April 1. Others will be published later.

The Survey acknowledges its indebtedness to all of these colleagues, who have contributed their time and effort to this admittedly arduous task.

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THE FORWARD MARCH OF RESEARCH ON CEREAL DISEASES

V. F. Tapke and R. W. Leukel

In December 1620 when the Pilgrim Fathers landed at Plymouth, Massachusetts there were some 800,000 Indians occupying the 1,900,000,000 acres of land that now constitute the United States of America. About 2,400 acres of land were available for producing the food of each person. Today our many millions are fed and clothed abundantly with only 14 acres of land per person. Plant pathologists have had a part in making this possible through developing a knowledge of how to save crops from the ravages of disease. What can happen when a disease runs rampant is illustrated by the destruction in a single year of World War I of about 300 million bushels of wheat in the United States and Canada. This loss was due to a pathogenic micro-organism that causes stem rust. Cereals and other crop plants are continually threatened by myriads of disease-producing organisms. Each species of the latter may comprise numerous pathogenic strains and new ones are continually being produced by natural process of mutation and hybridization. Even though only a relatively small percentage of the new ones may be more dangerous than those now in existence, past experience shows clearly the imperative necessity for continued alertness to detect new diseases or new forms of old ones.

The need for never-ending vigilance against new diseases and of coping with established diseases has long been recognized in our country and, better still, combative measures have kept pace with the country's growth. For example, the seed of what is now a huge spreading tree, the Division of Cereal Crops and Diseases, appears to have been sown with the hiring of a plant pathologist in 1894. He was M. A. Carleton, brought into the old Division of Vegetable Pathology and Physiology by B. T. Galloway. Today the Division of Cereal Crops and Diseases employs 17 full time and 2 part time pathologists and carries on cooperative projects with practically every State in the Union, and also in Canada and Mexico. Carleton proved a brilliant worker and set the pattern of things to come. In 1898 he visited Russia and other notable grain-producing countries and brought back varieties of durum and bread wheats and other grains, some of which have been of great value under certain of our conditions. In the severe rust epidemic of 1904, Carleton noted the high degree of resistance of Yaroslav emmer and Lumillo durum wheat. Twelve years later McFadden crossed Yaroslav with Marquis wheat. Out of this cross came Hope and H44, varieties that enter into all modern rust resistant wheats except Thatcher. Lumillo went into the breeding of Thatcher.

In his recent book on Diseases of Field Crops, Dickson describes a total of 130 diseases of barley, corn, flax, millet, oats, rice, rye, sorghum and wheat. Some of these diseases, like cancer in man, are very difficult to cope with. Many take a tremendous toll. The ultimate objective of the field, greenhouse and laboratory studies of cereal diseases is to devise means of eliminating the menace of diseases to cereal crops.

An account of the numerous projects that have made valuable additions to our knowledge of cereal diseases since Carleton's time is not intended herein, but among the outstanding accomplishments the following may be noted:

The discovery of physiologic races of cereal-disease fungi such as the rusts, smuts, mildews, etc. and the use of differential hosts to separate them or distinguish one from another.

The discovery of the relation between scab in wheat and barley and gibberella in corn, and its relation to control measures.

The original study of "take-all" of wheat and the gradual inclusion of studies on foot rots and root rots and later on the virus diseases of cereals.

Studies on diseases at first ascribed to fungi but later found to be physiologic, as: straight head of rice, flax canker, weak neck of sorghum, etc.

Studies on the cause and nature of corn diseases and on methods for their prevention and control.

Histologic studies on the relation of host and pathogen in different cereal diseases.

The writers have chosen arbitrarily two lines of research to illustrate the methods and progress of cereal disease control namely, stem rust of wheat and the control of various diseases through seed treatment. Progress made in this work has been the result of the cooperative efforts between the Division of Cereal Crops and Diseases, U. S. Department of Agriculture and many State Experiment Stations.

SOME ACCOMPLISHMENTS OF RESEARCH ON STEM RUST OF WHEAT

Wheat is the chief food of man at least in the temperate climates of the world. It is grown on some 72 million acres and produces around a billion bushels a year in the United States. Probably no disease has caused greater or more spectacular damage to this great crop than has stem rust. The causal fungus multiplies by means of several kinds of spores. Those that spread the disease from one wheat plant to another are cylindrical in shape and about one thousandth of an inch in length. On a single acre of wheat moderately rusted there about are 10,000 billion of these spores. They can be carried far and wide by the wind. For example, countless billions were blown northward from Texas, Oklahoma and southern Kansas during a period of moderate to strong south winds in 1925. In a week they infected an area of 250,000 square miles.

The breeding of wheat for resistance to stem rust was begun in 1904. The problem is complex because more than 200 pathogenic strains or physiologic races of the parasite exist. A wheat variety may be immune from some races, resistant to others and completely susceptible to still others. Furthermore the prevalence of races varies from year to year and from place to place. The causal fungus moreover also attacks the common barberry producing a sexual stage on this host that may give rise to new races by hybridization between existing races. The eradication of barberries delayed the seasonal onset of early rust in the northern half of the country and also reduced the opportunity for the development of new races. But in southern United States and Mexico, rust exists independently of barberries and then spreads to the north in the spring and early summer months. Consequently resistant varieties are a necessary adjunct in rust control. The United States Department of Agriculture and the Minnesota Agricultural Experiment Station initiated a program of developing wheats resistant to stem rust about 1905. Crosses were made between bread wheats and durum or macaroni wheats since the latter appeared to have some rust resistance. Unfortunately many of the hybrids proved highly susceptible to foot rot and were discarded. More discouraging, a linkage was found between the durum character and resistance to rust. However, through growing large populations of many different hybrid lines, a few plants from a cross between Marquis bread wheat and Iumillo durum wheat eventually were found that possessed the long sought combination of bread wheat characters and durum resistance to rust. The Marquillo variety was developed from one of these plants but it had a number of weaknesses. It was susceptible to root rots, its flour was yellowish, and its rust resistance is not as consistently high as desired.

The Kota variety came into prominence due to its unusual rust resistance for a common spring bread wheat. Kota however was highly susceptible to orange leaf rust, loose smut and stinking smut in addition to having a weak straw. It was crossed with Marquis, and one of the selections from this cross was named Ceres. This wheat had stiffer straw than Kota and was equal to the latter in stem rust resistance. Ceres wheat was distributed in 1926 and rapidly gained in favor. By 1934 more than four million acres of this variety were grown. However, while Ceres was gaining in popularity, a new physiologic race of the rust fungus capable of devastating Ceres came into being. It was race 56 first identified in 1928. It spread rapidly and in 1935 Ceres succumbed heavily to a terrific epidemic of rust due to a combination of factors extremely favorable to the race 56 and certain other stem rust races.

The next rust resistant variety in the march against stem rust was Thatcher, a product of the double cross (Marquis x Iumillo) x (Marquis x Kanred). Thatcher possesses the spring habit and high quality of Marquis, one type of rust resistance from Iumillo and another from Kanred. It is susceptible to the orange leaf rust but it stands up well against the prevalent races of stem rust.

McFadden's production of the Hope and H44 wheats has been noted above. In recent years these two have been used extensively in crosses with the better varieties. Many of the hybrids have shown near immunity from stem rust.

Seedlings of Hope wheat are resistant to many physiologic races of rust, and highly susceptible to others but as the plants grow older they are usually resistant to all races. Hope wheat, therefore, has a type of resistance that gives it great value as a parent in breeding for rust resistance. Adult plants of Hope have rusted heavily at times however under field conditions in Peru and under experimental greenhouse conditions.

Conclusive evidence has been obtained in recent years that new parasitic races of pathogenic fungi may arise through mutation and hybridization. While man is breeding disease resistant crops nature simultaneously is fashioning new strains of the crop pathogens. Obviously, then, continuous research and alertness is essential to keeping abreast with an ever changing situation.

PROGRESS IN CEREAL-DISEASE CONTROL THROUGH SEED TREATMENT

In dealing with a newly discovered plant disease, the plant pathologist's first aim is to discover the identity of the causal organism; his second is to determine its method of spread, and finally he aims to control or to prevent the spread of the disease. While the development of cereal varieties resistant to plant diseases is the ideal method of disease control and the one ultimately sought, it is usually a long-time process. It is highly desirable, meanwhile, to find other methods of prevention, especially for diseases that are spread only by seed-borne pathogens. The proper application of effective fungicides to the seed is the method generally recommended for the prevention of losses due to such diseases.

Some diseases that are seed-borne are also spread by infested soil or crop residues. In such cases seed treatment must be combined with or supplemented by certain cultural practices in order to effect satisfactory control.

Such diseases, as well as those that are entirely soil-borne, are generally combated by crop rotation, sanitation, early or late sowing, or other cultural practices, before and often after resistant varieties have been developed.

The control of diseases that are spread solely by air-borne spores must necessarily be confined largely to the development of resistant varieties, as previously described for the rusts.

The story of cereal seed treatment and its development during the past half-century furnishes an interesting chapter in the history of cereal-disease control, for great advances were made during that period. Seed treatment of wheat with copper-sulfate as a bunt preventive was first suggested by Schulthess as early as 1761 but Kühn in 1866 was the first to evolve a practical formula for its use. The use of hot water for the prevention of all seed-borne cereal smuts was developed by Jensen in 1888, and the use of formaldehyde for controlling some of these smuts was introduced by Bolley in 1896.

Thus, at the start of the century there were but three materials suitable for disinfecting cereal seeds for the control of certain seed-borne diseases, and all three had to be applied with great care to avoid injuring the seed. Copper sulfate was used for the control of bunt in wheat; formaldehyde, in addition to controlling bunt was found to be effective also in controlling the smuts of oats and the covered smut of barley; while the exacting and laborious hot water treatment, although effective in controlling all of these diseases, was used mostly for preventing the deep seated loose smuts of wheat and barley.

In 1920 Mackie and Briggs, following the work of Darnell-Smith in Australia, demonstrated the effectiveness of copper carbonate dust for the control of bunt in the United States, and in a few years this material largely replaced formaldehyde and copper sulfate for this purpose.

In the meantime, certain organic mercury compounds, such as Chlorophol, Germisan and Uspulun, were introduced into this country from Germany. When used as solutions of .2 to .5 percent in which seed was soaked for one-half to one hour, these materials effected excellent control of all seed-borne cereal diseases except the loose smuts of wheat and barley, and without injury to the seed. In fact, germination and stand were frequently improved. But, like the copper sulfate and the formaldehyde soak treatments, they were wet treatments, laborious and disagreeable to apply, and never attained wide popularity. Copper carbonate had pointed the way to a more simple and convenient form of seed treatment for seed wheat and thus had created a demand for a similar form of treatment for other cereal seeds. Chemical companies, therefore, directed their efforts toward the formulation of organic mercury compounds that could be applied in dust form. As a result, research workers, both Federal and State, for a time were deluged with a large number of experimental dusts made by different concerns, many of whom had not even subjected their product to preliminary tests. Many such materials also were imported from Europe, where research on dust seed treatments was advanced somewhat farther than in the United States. Some readers will remember such names as Segetan, Fusariol, Porzol, Abavit, Tutan, Höchst, Tillantin, Agfa, Urania, S.F.A. No. 225, and others. Concerns in this country produced materials with such names as: Wa Wa dust, Mercury C, Bayer Dust, Corona, Seed-O-San, Sterocide, Sanoseed, Acco Dust, Karasch A, Smuttox, Cuprobol, Semesan and Ceresan. Of all these products, only the last two are still sold on the American market.

Some of the materials that were tested were effective in controlling seed-borne diseases of

cereals but were objectionable because of their relative cost, their extremely poisonous nature, their corrosive effect on metal, their narrow margin of safety, their rapid loss of effectiveness, or for other reasons. Many, of course, were rejected because of their fungicidal ineffectiveness. After many experiments with various materials, the following set of requirements for the ideal seed-treatment fungicide in dust form was evolved:

1. It should be effective in disease control.
2. It should not injure seed even when applied at twice the recommended dosage, i. e. it should have a wide "margin of safety."
3. It should be reasonable in price, abundantly available, and easily applied.
4. It should adhere readily to the seed.
5. It should be non-corrosive to metal.
6. It should be stable, and not lose its effectiveness readily.
7. It should not be extremely poisonous or disagreeable to operators.

Needless to say, the ideal fungicide for cereal seed treatment has not yet been developed but a fairly-close approach to it has been made.

The first organic mercury dust fungicide to meet with wide success as a cereal seed treatment in the United States was Ceresan (2 percent ethyl mercury chloride), which was first marketed in 1928. It was effective in the control of all cereal diseases generally amenable to control by chemical seed treatment. However, the recommended rate of application of 2 to 3 ounces per bushel made its high cost -- 9 to 14 cents per bushel of seed treated -- an impediment to its wide-spread use for cereal seed treatment. New Improved Ceresan (5 percent mercury phosphate) appeared on the market in 1933. The recommended rate of application -- 1/2-ounce per bushel -- reduced the cost of material for treating seed to less than 3 cents per bushel. This material largely replaced the original "2%" Ceresan, which has since been used for treating cotton seed, peas, and seeds of certain ornamentals.

In 1948 these two Ceresan products were supplemented by "Ceresan M" (7.7% ethyl mercury sulfonamide). This material, while fully as effective as its predecessor, New Improved Ceresan, is less disagreeable, less dusty, less vesicant, and less poisonous. Another advantage of Ceresan M is the fact that it can be applied to seed grain as a "slurry", thus eliminating the hazard of flying dust. It is now being widely used for treating seed of cereals and other crops.

The story of corn seed treatment starts in the early twenties with the work of Holbert, Reddy, Erwin, Koehler and others. Some of the early experiments seemed to indicate that no benefit was derived from the practice of corn seed treatment. Later experiments, however, proved that the proper treatment of seed that is infected with *Diplodia* or *Gibberella*, or that has injured seed coats, results in better stands and increased yields. This is especially true if cold wet weather follows planting. At first, liquid treatments such as Chlorophol, Semesan, Corona and Uspulun were used, but these were gradually replaced by dust treatments such as Bayer dust, Corona dust, Merko, Sterocide, Barbak C and Semesan Jr.

These materials gradually disappeared from the market because of relative ineffectiveness, excessive cost or some of the other reasons previously mentioned. They have been replaced largely by the less poisonous non-mercurial organic compounds such as Arasan, Spergon and Phylon.

The wide-spread and ever-increasing use of high-priced hybrid corn seed gave a tremendous impetus to corn seed treatment. The seed companies that produce and sell hybrid seed, in order to guard against poor stands when unfavorable growing conditions follow planting, practically without exception treat their seed before selling it to the growers. Corn seed treatment, to a great extent, has thus been taken out of the farmer's hands. The use of large commercial treaters, effective fungicides, and trained personnel insure efficient treatment of most of the seed corn planted in the United States.

In reviewing the advances in cereal seed treatment during the past thirty years, the period of greatest advances in this field, perhaps the first accomplishment that should be mentioned is the development of relatively safe, effective and inexpensive organic mercury dust treatments, and the elimination of a host of inferior materials by continuous field and laboratory testing. The advent of thoroughly reliable seed treatment materials was followed by vigorous campaigns by extension workers to induce growers to treat their seed. This led to the development of itinerant portable seed-cleaning and treating outfits which move from farm to farm and, for a reasonable price per bushel, treat and clean the seed on the farm. There also were established many central cleaning and treating plants to which the growers haul their seed for cleaning and treating.

During the recent World War the shortage of mercury, which was essential in the manufacture of munitions, led to the production of effective non-mercurial organic fungicides. The extent of their usefulness was determined by extensive laboratory, greenhouse and field tests by State and Federal workers. Spergon and Arasan, for example, were found suitable for corn, rice, sorghum, flax, and wheat, but not for oats and barley. Although the non-mercurial organic materials are less poisonous than the organic mercurials, they have most of the objectionable features that are common to all dust fungicides. This led to the development of the slurry form of treatment, previously mentioned, whereby the dust fungicide is applied to the seed in a soupy water suspension which adds less than one percent of moisture to the seed and leaves the latter coated with the fungicide. This method necessitates the use of a special slurry treater which is too expensive for the average farmer to buy. It generally is used for custom treating at a central plant in connection with a seed-cleaning outfit as previously mentioned. It also is widely used by seed companies who sell treated seed.

The objection to dust treatments because of the discomfort due to flying dust, and the reluctance to use the cumbersome old wet methods of treatment, led also to another form of treatment - the "quick wet treatment." In applying this treatment, a somewhat concentrated solution of a volatile organic mercurial is sprayed onto the seed at the rate of 1 to 2 fluid ounces per bushel, after which the seed is thoroughly mixed, and then stored for at least a day or more to allow the fumes to penetrate to every seed. Special machines have been designed also for applying this type of treatment.

Panogen (2.1% methyl mercury di cyan diamide), a fungicide of this type, is now widely used for cereal seed treatment in some States and to some extent in Canada. So, in contrast to conditions at the time the Division of Cereal Crops and Diseases came into being, when cereal seed treatment was limited to the more or less hazardous use of hot water, copper sulfate, or formaldehyde, applied in a cumbersome, disagreeable manner, we now have a number of materials that are non-injurious to the seed and which can be applied easily and safely either by the grower or by commercial operators.

This great improvement in the cereal seed-treatment situation is the result of close cooperation between commercial chemical concerns and workers in the Division of Cereal Crops and Diseases, along with investigators located at agricultural experiment stations throughout the United States.

DIVISION OF CEREAL CROPS AND DISEASES

PLANT DISEASE RESEARCH ON FORAGE CROPS IN THE BUREAU OF PLANT INDUSTRY, SOILS, AND AGRICULTURAL ENGINEERING

Howard W. Johnson

INTRODUCTION

Research on the diseases of forage crops was conducted by plant pathologists in the Office of Cotton, Truck, and Forage Crop Disease Investigations, and later in the Office of Vegetable and Forage Diseases, for a period of years prior to a reorganization of the plant disease research of the Bureau in 1926. At that time, two pathologists were transferred to the Division of Forage Crops, where their researches have been continued for approximately 24 years. As the research on diseases of forage crops increased in scope, this was recognized in 1928 by a change in name to the Division of Forage Crops and Diseases.

The Division now employs nine plant pathologists for full time work on forage crops diseases. In addition, cooperative agreements are in existence with three State experiment stations, under which the Division pays a portion of the salary of a plant pathologist working on forage diseases while the State pays the remainder of the salary. In still other States, pathologists are under appointment in the Division as collaborators without pay and direct the work of a graduate student employed by the Division on a part-time basis for work on a specific forage disease problem. This increase in the number of plant pathologists working on forage crops diseases during the past twenty-four years is indicative of the increased importance legumes and grasses have assumed in American agriculture during that period.

While the early work on forage diseases in the Bureau centered largely around the diseases of cowpea, alfalfa, and clover, the importance of diseases in the culture of winter legumes was recognized later and work was started on the diseases of winter pea, vetch, and lupine. The greatly increased use of grasses, which resulted from the agricultural adjustment and soil conservation programs, emphasized the need for more knowledge of the diseases of hay and pasture grasses. Still more recently, the rapid increase in soybean acreage during the period of World War II, when soybean imports from the Orient were cut off, resulted in an increase in the prevalence of diseases on this crop and led to the initiation of a broad program of research on soybean diseases.

Because of the nature of forage legumes and grasses, direct disease control measures, such as spraying and dusting, have only limited application. Control must be sought in most cases through the development of disease-resistant varieties by selection or hybridization. For this reason, forage crops pathologists have always worked in close cooperation with the legume and grass breeders of the Division and the State agricultural experiment stations.

The research on forage crops conducted by the Division is organized into six main areas, as follows: (1) Alfalfa; (2) Clovers; (3) Soybeans, (4) Lespedeza, Cowpea, and Miscellaneous Legumes; (5) Hay and Pasture Grasses; and (6) Turf. The plant disease research summarized in this paper is organized under these same six headings. More detailed consideration is given the work done on the blind seed disease of perennial ryegrass and on the brown stem rot of soybeans in separate sections of the paper following these six summaries. These two diseases were selected as typical examples of the problems and methods involved in the investigation of forage crops diseases, and both illustrate the achievement of a practical control that is proving of extreme value to farmers.

ALFALFA DISEASE INVESTIGATIONS

A study of the foliage diseases of alfalfa was started in 1916 in cooperation with the Wisconsin Agricultural Experiment Station. Special attention was given to the leafspot caused by the fungus *Pseudopeziza medicaginis* (Lib.) Sacc. It was found that the fungus lives over winter on dead leaves and that ascospores produced in the spring furnish the source of primary infection. The germinating ascospores were found to penetrate through the cuticle and epidermal cell wall of the leaf with the fungus mycelium developing into a small stroma about the point of entry. An apothecium is produced on the stroma in about two weeks and the ascospores produced in this structure cause secondary infections. No spore form other than the ascospore was found to occur in nature.

During the course of the above studies, it became evident that another disease which had not previously been mentioned as occurring on alfalfa in the United States was responsible, under certain conditions at least, for even greater damage to the crop than the well-known leaf-

spot. This disease was identified as yellow-leafblotch caused by the fungus Pyrenopeziza medicaginis Fckl. The name of this fungus was changed in 1932 to Pseudopeziza jonesii Nannf. It was found that this fungus also overwinters on dead leaves and that infection takes place only from ascospores, which upon germination are able to penetrate the epidermal cells of the leaf. In contrast to the leafspot fungus, the leafblotch parasite produces conidia in abundance in pycnidia that develop in the lesions on living leaves. However, the conidia appear to be incapable of germination and no infections were obtained by conidial inoculations.

Since the only source of infection is the ascospores, it appeared that cutting the alfalfa before these mature on the killed portion of the leaves should greatly reduce the disease. Field observations confirmed this hypothesis, since leafblotch was found to be relatively unimportant in fields cut for hay at the stage usually recommended. It was observed, however, that if infected fields were allowed to remain uncut for an unusually long period, especially in the cool, moist weather of spring and autumn, the disease became abundant and destructive.

Another disease of alfalfa worked on by Bureau pathologists at about this same time is crownwart caused by the fungus Urophlyctis alfalfae (Lagh.) Magn. This disease had been found scattered through several important alfalfa-growing regions in the western part of the United States during the period of 1909 to 1914. A publication dealing with the disease in South America indicated that it might become of considerable economic importance and it was felt that prompt study might reveal the possibility of effective measures against further spread of the disease into other alfalfa-growing regions of the United States.

It was found that infection with Urophlyctis occurs through the very young buds of the alfalfa plant and only in early spring when excessive moisture is present. The galls were found to reach full development early in the summer and to deteriorate rapidly thereafter, only a few surviving until the following spring. No evidence of resistance to the disease was found and it was recommended that growers in the infested region attempt to prevent an excess of moisture in the soil in the early spring, when infection takes place, through drainage or a diminished supply of irrigation water.

The disease has not become more serious in the Western United States, nor has it become troublesome in the central and eastern alfalfa-growing regions, although it has been observed in Clay County, Mississippi, on alfalfa. It appears that the limited distribution of the disease to certain regions of the country is due to climatic conditions which favor the development of the fungus in these localities, rather than to factors which have prevented the spread of the causal organism.

In 1923, the alfalfa eelworm or stem nematode disease was reported as occurring in some of the irrigated valleys of the Western United States. The disease is localized in the crown of the plant and swollen buds and sprouts and enlarged brown stems are characteristic symptoms. The diseased condition is caused by a parasitic nematode or eelworm, Ditylenchus dipsaci, which penetrates the young, tender plant parts and whose presence stimulates the swellings and abnormal development. These organisms may be carried long distances by irrigation water or by hay. In hay, the nematodes show remarkable resistance to drying, since living nematodes have been recovered from hay samples five months after the alfalfa was cut and cured under normal conditions. Spread over shorter distances is accomplished by farm implements.

Alfalfa strain tests in the infested areas have demonstrated in recent years that certain alfalfa introductions from Turkistan are resistant to attack by the stem nematode. Seed of one of these introductions has been increased and released under the variety name "Nemastan" for growth in the nematode-infested areas. Recently, it has been discovered that the stem nematode is present and destructive on alfalfa in at least one area in Virginia. It appears, therefore, that these nematode-resistant alfalfa selections may prove of value in the Eastern United States, as well as in the West where they were made.

A Fusarium wilt of alfalfa, first found in September 1926 near West Point, Mississippi, was described in 1928 and the causal organism was identified as Fusarium oxysporum Schlecht. var. medicaginis Weimer. The leaves of plants affected by this disease turn yellow, the tips of the stems frequently wilt, and the plants eventually die. Frequently, one or more stems of an infected plant wilt and die while the rest of the stems appear healthy for a longer time. The vascular region of diseased plants, especially of the taproot, is usually some shade of brown in contrast to the creamy white color of the roots of healthy plants. Studies of the influence of soil moisture and temperature on infection by this fungus, showed that 55 percent soil moisture was more favorable for infection than was 35 percent and that the optimum temperature for infection was near 25° C.

The yellowing of alfalfa caused by the potato leafhopper, Empoasca fabae (Harris), has been studied over a period of years in cooperation with the entomologists of the Bureau of Entomology

and Plant Quarantine. It was shown that the yellowing, reddening, and dwarfing of alfalfa caused by infestation with this insect was not due to the transmission of a virus but appeared to be due to disruption of the functions of the vascular tissues caused by the leafhopper in its feeding upon the veins of stem tips, petioles, and leaf blades. Similar symptoms were produced by girdling alfalfa stems by means of live steam and it was shown that the chemical changes in leaves reddened and yellowed by artificial girdling and by the feeding of the potato leafhopper are essentially the same.

The work demonstrated that in addition to the marked reduction in yield caused by heavy infestations of this insect, the hay produced is lower in grade, contains less protein, and contains only about one-half the pro-vitamin A present in green alfalfa protected from leafhoppers by dusting or caging.

The most effective control for this insect-induced, disease-like injury would be the development of resistant alfalfa varieties. Work is still in progress on the selection of alfalfa strains resistant to the leafhopper yellowing and it is probable that in the future such resistance will be incorporated in some of the new, disease-resistant varieties that will be produced by the plant breeders working on alfalfa improvement.

Alfalfa dwarf, a disease that occurs only in southern California and whose symptoms and effect on alfalfa stands are quite similar to those of bacterial wilt, was shown in 1936 to be caused by a virus that could be transmitted by grafting. Since then, pathologists and entomologists of the University of California have shown that the virus causing alfalfa dwarf is the same as the virus causing Pierce's disease of the grapevine and that 14 species of leafhoppers can transmit the virus from diseased to healthy plants.

A root rot of alfalfa, found almost simultaneously at Riverside, California, and Madison, Wisconsin, was described in 1938 and the causal fungus was shown to be Stagonospora meliloti (Lasch.) Petr. known previously only as a leaf-spotting fungus of several legumes. The ascigerous stage of the fungus was found to develop on alfalfa stems in the spring and was identified as Leptosphaeria pratensis Sacc. & Briard. The root rot involves the upper part of the taproot and the crown branches. The surface of the lesion is dark brown to black in color while beneath the surface the tissues are reddish brown to almost black. Characteristic wedge-shaped discolorations extend from the bark toward the center of the root. The root rot progresses slowly and is favored by high soil temperatures.

In 1940 a foliage disease of alfalfa and red clover caused by the fungus Stemphylium botryosum Wallr. was reported from Wisconsin. The ascigerous stage of the fungus was found on dead red clover stems and developed in culture on sweetclover stems and potato-dextrose agar. It was identified as Pleospora herbarum (Fr.) Rab. and was shown to be homothallic. The lesions caused by this fungus on alfalfa leaves appear as dark-brown sunken areas that are often surrounded by a straw-colored halo. Concentric zones sometimes develop in old lesions. Conidiophores are produced either singly or grouped in fascicles on such lesions and the conidia are olive brown in color, muriform and have echinulate walls. This organism infects the seeds of several forage legumes.

Rhizoctonia root canker caused by the fungus Rhizoctonia solani Kuehn was shown in 1943 to be a factor in shortening the productive life of alfalfa stands grown under irrigation in southern California and southwestern Arizona. This disease is characterized by dark, slightly sunken areas on the tap root and large lateral roots. The lesions usually occur where young roots have emerged from larger roots. Soil temperatures of 25° to 30° C. were found to favor the development of the disease, while little disease developed at soil temperatures below 20° C. Field observations had revealed previously that the alfalfa plants died out during the summer months, but not during the cooler parts of the year, thus suggesting a close correlation between disease development and warm soil temperature.

In 1940, three species of Colletotrichum were reported as occurring on alfalfa in the Southeastern United States. Two species have straight spores, those of C. trifolii Bain & Essary being mostly 10 to 12 microns long and those of C. destructivum O Gara being mostly 14 to 18 microns long. The third species has spores distinctly curved and about 25 microns long, thus resembling C. graminicolum (Ces.) G. W. Wils. The most commonly reported species is C. trifolii and it appears that this fungus is the cause of much of the anthracnose observed on alfalfa in this region. Lesions are formed on the stems and petioles of the attacked plants and the parts above the lesions wilt, the leaves becoming pale and bleached. More serious damage is caused when infection of the crown and taproot occurs since this results in the wilting and death of entire plants. Anthracnose appears to be a factor in shortening the productive life of alfalfa stands in the Eastern United States and at present is receiving consideration in the alfalfa improvement program in that region.

It was demonstrated in 1925 that the alfalfa wilt disease prevalent in Kansas and Nebraska was caused by a bacterium, Corynebacterium insidiosum (McCul.) Jensen. Since that time bacterial wilt has been found to occur throughout most of the alfalfa-growing areas of the United States and much of the disease work related directly to alfalfa improvement has centered around the testing of varieties and strains for resistance to this important disease. The production of two new bacterial wilt-resistant varieties of alfalfa, Ranger, and Buffalo, through cooperative efforts of the Division and the Nebraska and Kansas Agricultural Experiment Stations, respectively, has eased the strain on this work to some extent in the past few years. As a result, more attention has been devoted to some of the less critical diseases such as leafspot, leaf blotch, stem rot, black stem, anthracnose, rust and downy mildew. Attempts are being made to secure strains of alfalfa resistant to these diseases, so that such resistance can be incorporated into the bacterial wilt-resistant varieties. Since 1934, this program of work has been integrated through the annual meetings of "The Alfalfa Improvement Conference".

CLOVER DISEASE INVESTIGATIONS

Because of its close resemblance to the similar disease of alfalfa caused by Pseudopeziza medicaginis (Lib.) Sacc. the leafspot of red clover caused by the fungus Pseudopeziza trifolii (Biv. Bern.) Fckl. received attention in studies undertaken in 1916 in cooperation with the Wisconsin Agricultural Experiment Station. Efforts to cross these fungi from one host to the other were not successful, however, and it was concluded that the morphological and physiological differences were sufficient to retain the two fungi as distinct species.

This disease is found only on the clover leaves and the spots are dark olive color in the early stages, becoming brown or almost black in later stages. Fruiting disks are not as a rule found on the spots while the leaf is still alive, but they develop abundantly after the death of the leaf. On dead leaves they appear as amber drops of jelly in wet weather, but when dried they become small and inconspicuous. The fungus was found to overwinter on dead clover leaves and the ascospores produced in the spring furnish the source of new infection. As in the case of the similar parasite of alfalfa, the ascospore appears to be the only spore form that occurs.

An investigation of diseases as a factor in "clover failure" led to a study of the two principal anthracnose-producing fungi of red clover, Colletotrichum trifolii Bain & Essary and Kabatella caulivora (Kirchn.) Karak. The results of this study were published in 1928 and showed that while the macroscopic symptoms produced by these two fungi on red clover were nearly identical, differences existed in spore characters, setae, and host range. It was concluded that these differences fully justified separation of these fungi as distinct species.

In fields severely affected with anthracnose, the most conspicuous symptom is that of drooping leaflets and flower heads. The drooping parts soon wilt and turn brown, and as more serious infection kills whole stems or entire plants, the field becomes spotted with brown areas. In severe cases fields appear as if injured by fire, which has led to the name "scorch" being used in some localities to designate anthracnose. In addition to the lesions on the petioles, flower stalks and stem, these fungi cause a spotting of the leaves and may infect and rot the crown and upper portion of the taproot.

The anthracnose caused by C. trifolii occurs most injuriously in the southern half of the clover belt of the United States, while that caused by K. caulivora is more common in the northern half. Infection experiments conducted at constant air temperatures showed that the optimum for the development of anthracnose caused by C. trifolii is about 28° C. This temperature response is cited as the cause of the southern distribution of this disease.

Control by means of resistant varieties was suggested as offering the most promise and attention was called to the fact that red clover seed from stock produced in regions where the disease is regularly severe is in general much more resistant to anthracnose than are strains of red clover from other regions. Because of the characteristics of the anthracnose disease, the process of natural selection plays an important part in increasing the degree of resistance in red clover grown continuously in an anthracnose-infested region.

Cooperative efforts of the Division and several of the State agricultural experiment stations along the lines suggested above have resulted in the production of two new varieties of red clover that are now widely grown. Cumberland, which is adapted to the southern part of the red clover growing area, possesses considerable resistance to Colletotrichum anthracnose since it originated from selected strains of red clover grown for many years in Tennessee, Kentucky, and Virginia, where they have been exposed regularly to severe natural outbreaks of this disease.

Similarly, the variety Midland was developed from old Corn Belt strains of red clover and

is adapted to the northern part of the red clover belt where it demonstrates some resistance to Kabatiella anthracnose, as a result of the natural selection that had occurred in these old strains.

More recently, the red clover variety Kenland has been released through cooperative efforts of the Kentucky Agricultural Experiment Station and the Division. The strains making up this variety were first exposed to artificially induced epidemics of Colletotrichum anthracnose and later to stem rot and other clover diseases over a period of several seed generations, with seed harvested from the surviving plants. This variety, therefore, has a somewhat broader base of disease resistance than any previously released red clover; and, consequently, many of the plants persist into the third or fourth years of growth.

Studies of the powdery mildew disease of red clover caused by the fungus Erysiphe polygoni DC. were undertaken in cooperation with the Purdue University Agricultural Experiment Station and were continued in cooperation with the Wisconsin Agricultural Experiment Station. In a report of this work published in 1936, three physiologic forms of red clover powdery mildew were distinguished by differences in the reaction of certain red clover clones. It appeared from the limited tests made with mildew collections from various locations that form 1 is widely prevalent, whereas, forms 2 and 3 are relatively rare.

It was shown also that the red clover powdery mildew fungus manifests a definite diurnal cycle, certain phases of fungus activity occurring regularly at a certain time of the day. For example, practically all of the conidia formed during the 24 hours of the day were found to mature between 8:00 a. m. and noon. It was concluded that the alternating light and dark of the normal day are responsible for the cyclic manifestations of the fungus.

The selection of powdery mildew-resistant red clover plants followed by controlled crossing between these resistant selections and brother-sister mating within the lines thus established has been carried on over a period of approximately 15 years in cooperative work of the Division and the Wisconsin Agricultural Experiment Station. Several of the powdery mildew-resistant red clover lines developed in this way have been used in making synthetics. Seed of one such synthetic has been increased and is now being tested widely prior to release as a powdery mildew-resistant variety of red clover.

A leafspot disease of red clover caused by the fungus Stemphylium botryosum Wallr. was reported from Wisconsin in 1940. The ascigerous stage of the fungus was found on dead red clover stems and was identified as Pleospora herbarum (Fr.) Rab. The leaf lesions caused by this fungus on red clover are irregular in shape and dark brown to black in color. A straw-colored halo often develops around each lesion. Small black linear lesions are produced on stems and petioles, but the fungus appears to cause most damage as a leafspot. The conidia formed by this fungus are echinulate which serves to differentiate it from a closely related fungus, S. sarcinaeforme (Cav.) Wiltshire, with smooth-walled conidia that causes a similar leafspot on red clover.

Clover rust, caused by the fungus Uromyces trifolii (Hedw. f.) Lév., attacks all of the common clovers and is sometimes severe enough on white, alsike, and red clovers to cause loss of leaves and thus reduce the yield obtained. In 1941, workers at the U. S. Regional Pasture Research Laboratory reported that rusted leaves of white clover contain from one-fifth to one-third less carotene (pro-vitamin A) than do non-rusted leaves. It would appear, therefore, that the nutritive value, as well as the yield, of the clover crop is reduced by clover rust.

Stem rot of clovers, caused the fungus Sclerotinia trifoliorum Erikss., has been recognized in this country since 1890. It appears to be most prevalent in western Oregon and in the eastern part of the red clover-growing area. The fungus is most active in late winter and early spring when it rots the stem bases and upper taproot of the attacked plants. Serious outbreaks have been reported on crimson clover, red clover, white clover and sweetclover. Work reported in 1949 from the U. S. Regional Pasture Research Laboratory shows that this fungus is responsible for an extensive killing of Ladino clover stolons that becomes evident in the spring. It appears, therefore, that stem rot may be a major factor in the winter survival of this large-growing strain of white clover which has recently become one of the major pasture legumes in the United States.

A virus disease of Ladino clover characterized by stunted plants and chlorotic, yellow mottling of the leaves was described in 1949 as a result of cooperative studies conducted by the U. S. Regional Pasture Research Laboratory and the University of Pittsburgh. The disease was given the common name of "yellow patch" and the causal virus was identified from host range and other properties as a strain of alfalfa mosaic virus different from any previously described.

A blighting of sweet clover stems described in Germany in 1903 was first recorded in the United States in 1938 and the causal fungus was identified as Ascochyta caulicola Laub.

This fungus causes bleached areas, sometimes accentuated by a brown border, which are soon dotted with black pycnidia. In vigorously growing plants, it causes a characteristic bending of the stems and the common name "gooseneck" has been suggested for the disease. The fungus was isolated from the seed of diseased plants and appeared to be systemic to some degree.

Further studies published in 1939 showed that three other fungus parasites of sweetclover also infected the seed, i. e. Cercospora zebrina Pass., Leptosphaeria pratensis Sacc. & Briard, and Mycosphaerella lethalis Stone. No external evidences of the presence of these fungi in the seed were discovered. None of the fungi immediately attacked or damaged the seedlings bearing them and the extent to which this seed infection leads to the incidence of important diseases of sweetclover in agriculture remains to be determined.

A root rot of sweet clover that had been observed in the Corn Belt States since 1930 was described in 1939 and the causal fungus was considered to be Phytophthora megasperma Drechs. However, the same disease was found by a Canadian pathologist in Alberta in 1940, and the true parasite was identified as a strain of P. cactorum (Leb. & Cohn) Schroet. The existence of the root rot is first evident in the spring by the wilting and death of individual plants. When the roots of such plants are dug, a portion is found decayed. The disease is most abundant in low, wet portions of fields, where during seasons of heavy spring rainfall, it may destroy almost all of the plants quite rapidly.

Root rot-resistant sweetclover plants were obtained by inoculating fall-dug roots with the fungus in the greenhouse during the winter months. Selfed seed was obtained when these plants matured the following spring. Thirteen of these progenies were inoculated and gave 50 to 75 percent of healthy plants in comparison with 10 percent healthy plants from the progeny of an unselected sister plant. It appears, therefore, that resistance to Phytophthora root rot can be increased greatly by selection.

SOYBEAN DISEASE INVESTIGATIONS

Intensified soybean disease research in the past few years has revealed the existence of three diseases previously not known to occur on soybeans in the United States. These diseases are: (1) bud blight, a virus disease; (2) wildfire, a bacterial disease; and (3) brown stem rot, a fungous disease. Of these three diseases, brown stem rot perhaps causes the greatest losses, being particularly severe in Illinois where it was first discovered, but now becoming increasingly important in Indiana, Iowa, Missouri, and Ohio. This disease is discussed more fully in a later section of this paper. Wildfire, on the other hand, appears to be more prevalent and destructive on soybeans in the Southern States. Bud blight has been observed rather generally over the Corn Belt States, but severe outbreaks have occurred in only a few localized areas. It is rarely seen on soybeans in the South.

Major efforts in the soybean disease program have been directed toward determining the resistance of varieties and strains of soybeans to the three bacterial foliage diseases; i. e., blight, pustule, and wildfire. Disease readings have been made on the varieties and strains planted in uniform soybean nurseries at various locations in the twenty-four States cooperating with the U. S. Regional Soybean Laboratory. These field observations have been supplemented by artificial inoculation tests conducted in the greenhouse and in field plots. As a result of these studies, it has become apparent that none of the Corn Belt varieties of soybeans have a high degree of resistance to the bacterial foliage diseases, other than some varietal resistance to bacterial blight. On the other hand, two of the southern varieties, CNS and Ogden, have proved highly resistant to bacterial pustule and remain relatively free from wildfire. While blight attacks these varieties during the early part of the growing season, foliage injury is usually not extensive. Consequently, these two varieties have been used in numerous crosses in an attempt to obtain superior disease-resistant varieties of different maturities for the South.

Studies are underway on the method of over-wintering of these three bacterial parasites of soybeans; on the inter-relations of the three in mixed cultures and when inoculated on soybean plants; and on the effect of different environmental factors such as temperature, age of leaf, dilution of inoculum, variety of host, etc., on symptomatology.

Investigations of the pod and stem blight disease made in cooperation with the Iowa Agricultural Experiment Station have shown that two members of the genus Diaporthe occur on soybeans and that these differ in pathogenicity and type of perithecial development. A heterothallic form, identified as D. phaseolorum (Cke.) Ell. var. sojae (Lehm.) Wehm. has scattered, single perithecia and produces typical Phomopsis conidia. It is the less pathogenic of the two, attacking mainly mature plants and producing linear rows of pycnidia on branches and stems. A homothallic form, identified as D. phaseolorum (Cke.) Ell. var. batatatis (Harter & Field) Wehm.

produces caespitose clusters of perithecia and lacks conidial stages. It is an active parasite on soybeans, attacking and girdling the stems, and causing the plants to wilt and die.

Studies of the charcoal rot disease, made in cooperation with the Missouri Agricultural Experiment Station, have shown that isolates of the causal fungus, Macrophomina phaseoli (Maubl.) Ashby, vary considerably in their pathogenicity on soybeans. None, however, possess a high degree of pathogenicity on this host and infection appears to be limited to young seedlings, senescent plants, and plants growing under extremely unfavorable environmental conditions. The disease was found in commercial plantings only in a season of severe drought and high temperatures. The disease occurred most commonly on very sandy soils, in drill-seeded fields, in weedy fields, and at the border of fields. Low soil moisture levels were a major factor contributing to the development of the disease in both commercial plantings and greenhouse inoculation tests.

Downy mildew, caused by the fungus Peronospora manshurica (Naoum.) Syd., was considered to be strictly a foliage disease of soybeans in this country until 1942 when it was shown that the oospores of this fungus encrust the soybean seed, giving them a milky appearance. This condition has since been observed on soybean seed from numerous localities, and is apparently of rather common occurrence in all soybean growing areas of the United States. Studies have shown that when such seed are planted in the greenhouse, they give rise in some cases to downy mildew-infected seedlings with the lesions connected by mycelium in a systemic infection. Young plants with such systemic infection have been collected in the field and the characteristic mycelium of the downy mildew fungus has been found in all parts of the young plants through the hypocotyl and first trifoliate leaf.

Soybean seed treatment tests have been conducted in cooperation with the State agricultural experiment stations in the North Central, Southern, and Eastern States since 1943. These tests have shown that in many localities significant increases in stand result from treating soybean seed with a fungicide before planting. Arasan and Spergon have, in general, given somewhat better results than the other fungicides included in the tests. The most pronounced improvements in stand have been obtained with seed lots of rather low germinability and it appears that when weather conditions at harvest time in the fall are such as to cause damage to the soybean seed, seed treatment the following year may be advisable. In the Southern States, varieties that mature in September usually produce seed of lower viability than do those of October maturity. Treating the seed of these earlier varieties in this region may mean the difference between a satisfactory stand and a poor one in many years.

Dusting experiments have been conducted in cooperation with the North Carolina Agricultural Experiment Station since 1945 to determine the effectiveness of copper dust in controlling the leaf and stem diseases of soybeans, particularly the three bacterial foliage diseases. In some seasons, dusting has resulted in rather effective control and a significant increase in yield of seed. In other years, dusting has appeared to be rather ineffective. The variant results have been due apparently to seasonal weather conditions, timeliness of dust applications and various other factors.

In 1948, a severe infestation of purple seed stain, caused by the fungus Cercospora kikuchii Matsu and Tomoyasu, developed on soybeans in North Carolina. Counts of the purple-stained seeds on the harvest from the dusting test showed a reduction of 40 to 50 percent in purple-stained seeds as a result of dusting the soybean plants with tribasic copper sulphate. Further work on the dusting of soybeans to control diseases appears warranted, since in some areas of the South airplane dusting with the new organic insecticides is becoming a rather common practice to control such insect pests of soybeans as the bean leaf beetle, the cotton boll worm, and the velvet bean caterpillar.

LESPEDeza, COWPEA, AND MISCELLANEOUS LEGUME DISEASE INVESTIGATIONS

A wilt disease of annual lespedeza first observed at Arlington, Virginia, in the summer of 1937 was shown to be caused by a previously undescribed bacterium, Xanthomonas lespedezae (Ayers et al.) Burkh. The disease is now known to be widely distributed in the lespedeza-growing areas of the United States, but appears to be most severe on strains of Early Korean lespedeza in Illinois, Iowa, and Missouri. It has been shown that the wilt bacterium may occur either in or on the seed of annual lespedeza and it seems probable that this is the method by which the organism has been carried from region to region.

Powdery mildew of annual lespedeza is caused by the fungus Microsphaera diffusa Cooke & Peck. While this disease usually develops too late in the season to cause serious losses, it does

appear to cause a certain degree of premature defoliation. Strains of Common and Kobe lespedeza appear to be somewhat more susceptible to this disease than do strains of Korean, at least in certain regions.

An anthracnose of annual lespedeza caused by a strain of Glomerella cingulata (Stonem.) Spauld. & Schrenk was described for the first time in 1946. This disease is known to occur in Georgia, North and South Carolina, and Virginia. The disease is most conspicuous as a leafspot but lesions are produced also on the petioles and stems. Seedlings may be stunted or killed during the spring and early summer months and considerable defoliation may be caused but stands are never seriously depleted. Strains of Kobe and Common lespedeza (L. striata) are more susceptible to anthracnose than are strains of Korean (L. stipulacea.)

Some of the earliest work on cowpea diseases in the United States involved the testing of cowpea varieties for resistance to Fusarium wilt and root-knot on "pea-sick" soil near Monetta, South Carolina. As a result of these tests, the Iron variety of cowpea, which had been found in cultivation in Barnwell and Aiken Counties, South Carolina, was shown to be highly resistant and seed of this variety was distributed to growers in the Southern States. Later, Brabham and Victor, hybrid varieties of cowpea with Iron in their parentage, were likewise found to be resistant to wilt and root-knot.

One of the most serious and widespread diseases of cowpea observed in recent years is bacterial canker, caused by Xanthomonas vignicola Burk. It is interesting to note that Iron, Brabham, and Victor are among the varieties resistant to this disease and that these varieties are now being used in crosses to produce new, superior varieties of cowpea resistant to wilt, root-knot, and bacterial canker.

In some localities in the South, diseases became so destructive on Austrian winter peas about 1930 that the growing of this otherwise desirable winter cover crop was practically abandoned. To help meet this situation, the Division placed a plant pathologist at Experiment, Georgia. His surveys revealed that the most destructive diseases are: (1) leafspot and black stem caused by Ascochyta pinodella L. K. Jones and Mycosphaerella pinodes (Berk. & Blox.) Stone; (2) leaf blotch caused by Septoria pisi West.; (3) root rot caused by Aphanomyces euteiches Drechs.; and (4) powdery mildew caused by Erysiphe polygoni D. C.

Since a number of these fungi live over from one crop season to the next in the soil or in pieces of diseased stems, he recognized that the prevalence of the fungi in the soil would increase from year to year if peas were planted on the same fields each autumn. Observations in growers' fields and in rotation plots at the Georgia Agricultural Experiment Station led to the conclusion that if winter peas are planted on the same land not oftener than one year out of three or four, losses due to diseases will be greatly reduced. This recommendation was made to the growers.

Studies of varietal resistance to the diseases yielded little encouragement, so a program of hybridization was undertaken in an attempt to produce new, agronomically desirable, disease-resistant strains of winter peas. This work resulted in the production of three strains with considerable resistance to Aphanomyces root rot. Seed of one of these strains is being increased in Oregon and should soon be available to growers in the South. No resistance to leafspot and black stem was observed in these hybrids, but these diseases are rather effectively controlled by rotation as recommended above.

A leafspot of Augusta vetch was shown to be caused by the fungus Botrytis cinerea Fr. in 1944. Inoculation experiments showed that smooth and purple vetches were highly resistant to the disease, while Vicia sativa (all strains that were tested), V. grandiflora, and V. faba were susceptible in addition to V. angustifolia.

An anthracnose disease of vetches was described in 1945 and the causal organism was described as Colletotrichum villosum Weimer. This fungus causes both leaf and stem lesions that are quite similar in appearance to the lesions of the more common false anthracnose disease caused by Kabatiella nigricans (Atk. & Edg.) Karak. Inoculation tests showed that Vicia atropurpurea, V. villosa, and V. dasycarpa are the most susceptible species while V. sativa, V. grandiflora, V. monanthos, V. angustifolia, and V. pannonica are fairly resistant.

A greatly increased acreage of kudzu (Pueraria thunbergiana) has been planted in the Southeastern United States during the past 15 years as a result of the soil conservation program. These plantings have remained relatively free from diseases, except for a rather general infestation with bacterial halo spot caused by Pseudomonas phaseolicola (Burkh.) Dows. However, in 1947, a fungus leafspot was found on kudzu in several counties in Central and South Georgia. It appeared to be causing the premature shedding of many leaves and varying degrees of injury to others. The causal fungus was identified as Cercospora pueraricola Yamamoto. Cooperative investigations of a Division pathologist and one employed by the Georgia Agricultur-

al Experiment Station resulted in the discovery of the perithecial stage of the causal fungus on overwintered kudzu leaves and it was described in a 1948 publication as Mycosphaerella pueraricola (Yamamoto) Weimer & Luttrell. The common name "angular leafspot" was suggested for the disease and it was pointed out that this disease of kudzu had been reported from Formosa in 1934 and from China in 1936. It seems probable, therefore, that this fungus was introduced into the United States on kudzu seed imported from the Orient.

During recent years, three species of imported lupines, Lupinus angustifolius (blue lupine), L. luteus (yellow lupine), and L. albus (white lupine), have been grown experimentally in the Southeastern United States and the blue lupine has become established as a winter cover crop in the Coastal Plain sections of Georgia, Alabama, and northern Florida. As the cultivation of this crop increased, it became evident that it was susceptible to attack by a number of diseases.

In March 1943, an anthracnose of lupines not previously reported in the United States was described and the causal fungus was identified as Glomerella cingulata (Stonem.) Spauld. & Schrenk. Inoculation experiments showed that under conditions of high humidity this fungus attacks young plants of both blue and white lupine. Yellow lupine was not infected in the single test made with this species.

In April 1943, a cankering of the stem and branches of blue lupine was shown to be due to attack by the fungus Botrytis cinerea Fr. It was found that while frozen tissue is not essential for infection, it forms an excellent infection court for this fungus and that damage caused by late spring freezes may be considerably augmented by the fungus.

In 1944 some root rots and a foot rot of the three species of lupines were described. The root rots were shown to be caused by several species of Fusarium, by Rhizoctonia solani Kuehn, and by Pythium graminicolum Subr. The foot rot was shown to be caused by the common southern blight fungus, Sclerotium rolfsii Sacc. The pathogen most frequently isolated was Fusarium oxysporum Schlecht. f. radicis-lupini Weimer and it was concluded that this fungus is the most common cause of the root rotting of lupines found in the southeastern part of the United States. The selection of resistant strains of the hosts appears to be the most hopeful control measure for these diseases.

In December 1947, the leafspot disease of lupines caused by the fungus Ceratophorum setosum Kirchn. was found for the first time in the United States in a field of blue lupine near Perry, Georgia. An extensive survey of the major lupine-growing sections of the Southeastern United States made in March 1948, revealed that this disease, known by the common name "brown-spot", was present in all the localities visited in Georgia, Florida, and Alabama, and that in many places it was causing considerable defoliation from the base of the plants toward the top. In addition to the leafspot symptoms, it was observed that the fungus caused lesions on the petioles and stems. In some cases the stem lesions were in the form of large cankers resembling those produced by anthracnose.

Lesions similar in appearance to those observed on blue lupines were found on yellow and white lupines at two locations in Florida, thus showing that all three species of lupines are susceptible to attack by this fungus. Heavy rainfall and continued cloudiness throughout much of the Southeastern United States from November 1947 to March 1948 appeared to have retarded the growth of the lupines and to have been factors in accentuating the amount of damage from this disease.

Seed production of winter cover crop legumes in the Southeastern United States has been rather uncertain and much of the seed planted each fall has been purchased from seed producers in the Pacific Northwest. The blue lupine has been an exception to this general rule and yields of 1,000 to 1,500 pounds of seed per acre are quite common. The abundant seed crop it produces in the Southeast has been an important factor in the rapid increase in the acreage planted to blue lupine. The storing of this large seed crop from harvest in May until planting time in the fall has presented serious problems in this humid area and recently a project has been set up that is attempting to solve some of these problems. Since microbiological factors are among those involved in the storage of blue lupine seed, pathologists are participating in this project.

HAY AND PASTURE GRASS DISEASE INVESTIGATIONS

Some of the earlier work on grass diseases in the Bureau involved studies of the susceptibility of wild grasses to attack by certain cereal rust fungi and a rather extensive study of the graminicolous species of Helminthosporium. The initiation of an expanded program of grass breeding investigations by the Division in 1935, and the establishment of extensive grass nur-

series by the Soil Conservation Service at about the same time, provided a mechanism for evaluating grasses as species, varieties and strains under a wide variety of environmental conditions. Differences between varieties and strains in the breeding and soil conservation nurseries, including differences in susceptibility and resistance to diseases, soon became apparent and it was recognized that the investigation of grass diseases coincident with the breeding procedure was an essential phase of grass improvement. Recognition of this fact resulted in the setting up of an expanded program of grass disease investigations at that time.

The wide variety of grass species involved and the still wider range of parasites made it essential that considerable time be spent at first in survey work to determine the relative prevalence and economic importance of the various types of grass diseases. Hundreds of grass disease specimens were collected and examined and several extensive indices to the diseases observed on the various grass species were published in The Plant Disease Reporter.

When this data had been assembled, certain generalizations became evident. The paucity of smuts and stem rust on grasses in the Southeastern United States is very noticeable as compared with what is found in the more Central States and the Far West. Root rots also do not appear to cause the injury to grasses in the Southeastern States that they do in some of the more western sections of the country. On the other hand, ergots of grasses are widely distributed and rather common. Leafspots likewise are rather generally distributed but are usually much more prevalent in those regions where the climate is more humid.

Studies of the smut diseases of grasses have been conducted in the Pacific Northwest over a period of years in cooperation with the Soil Conservation Service and the Washington Agricultural Experiment Station. These studies have resulted in publications on the life history and physiologic specialization of four grass smuts of definite economic importance in this region, i. e., (1) stripe smut caused by Ustilago striiformis (West.) Niessl; (2) head smut caused by Ustilago bullata Berk.; (3) stem smut caused by Ustilago spgazzinii Hirsch.; and (4) flag smut caused by Urocystis agropyri (Preuss) Schroet. Other grass smuts of more mycological than pathological interest have also been studied.

Tests of the susceptibility of strains of various economic grasses to the more important grass smuts have been conducted by means of artificial inoculations and considerable strain differences in smut reaction have been noted. For example, certain accessions of blue wild rye, Canada wild rye, slender wheatgrass, and mountain brome grass submitted for testing by the Soil Conservation Service were found to be immune to certain of the smut diseases while other accessions were quite susceptible. Such information has been of value in determining what grass strains should go into seed production in the conservation nurseries, as well as in providing the grass breeders with smut-resistant or immune grass strains for use in hybridization.

Seed treatment tests for the control of head smut of grasses and for the improvement of stands by control of seedling diseases were conducted also as a part of this cooperative work. Of the materials tested, 2 percent Ceresan and New Improved Ceresan proved best, giving excellent smut control and from 300 to 500 percent better stands than the non-treated check plantings. On the basis of these results, either 2 percent Ceresan at 2 to 4 ounces per bushel weight of seed or New Improved Ceresan at 1/2 to 1 ounce per bushel were recommended for combined control of head smut and stand improvement.

A study of the prevalence and distribution of stripe smut in Kentucky bluegrass (Poa pratensis) pastures in Pennsylvania was made by workers at the U. S. Regional Pasture Research Laboratory. Sod plugs from each of 13 representative pastures were collected and observed periodically over a period of five months. The total number of plugs found to contain smutted plants varied for different pastures from 4.5 to 34.4 percent. The high percentage of smutted plugs collected from some of the bluegrass pastures leaves little doubt that stripe smut is important in reducing their productivity.

In further studies of the stripe smut of Kentucky bluegrass made at this laboratory, smutted plants were grown at different, controlled air temperatures. This experiment showed that both host and parasite grew well for five months at temperatures of 1.5°, 10°, and 20° to 25° C. At 32° C., on the other hand, only 14 out of 23 smutted plants were alive after four months, and 9 of these 14 plants showed no visible evidence of smut infection. When these plants were placed at a lower temperature and were permitted to grow for a time, smut symptoms appeared again in most cases. Chlamydospores removed from leaves of the smutted plants growing at 32° C. proved to be highly germinable without any after-ripening period, whereas, those from plants growing at 1.5°, 10°, and 20° to 25° C. failed to germinate unless after-ripened.

As part of the grass disease investigations conducted in the Pacific Northwest in cooperation with the Soil Conservation Service and the Washington Agricultural Experiment Station,

studies were made also of stem rust of grasses caused by the fungus Puccinia graminis Pers. An epidemic of stem rust developed on many grasses in the Pullman, Washington, area during the summer and fall of 1940 and collections were made on big bluegrass (Poa ampla), on wild oats (Avena fatua), and on blue bunch wheatgrass (Agropyron spicatum). One hundred and twenty-three species of grasses and cereals, in 23 genera, were used in host-range studies with these three collections of stem rust. The Poa rust culture infected 34 species representing 14 genera of grasses, the Avena rust culture infected 18 species in 9 genera, while the Agropyron rust culture infected only 7 species representing 3 genera of grasses.

The culture of stem rust from Poa ampla was identified as a new physiologic race of Puccinia graminis avenae Erikss. & E. Henn. occurring primarily on grasses. The culture from Avena fatua was identified as physiologic race 2 of P. graminis avenae. The culture from Agropyron spicatum did not seem to belong to any known variety of P. graminis and was thought to be a new variety of stem rust that is highly specialized to Elymus glaucus and a few species of Agropyron and Sitanion.

Studies of the reaction of collections of meadow fescue, Festuca elatior, and of tall fescue, F. elatior var. arundinacea, to crown rust, Puccinia cornata Cda. by workers at the U. S. Regional Pasture Research Laboratory were reported in 1947. They found that most collections of meadow fescue (14 chromosomes) are susceptible while those of tall fescue (42 chromosomes) are usually resistant. However, one collection of meadow fescue obtained from Maine was immune to this rust. The discovery of rust-immune material in the 14-chromosome condition should simplify the transferring of rust resistance to strains of F. elatior that are agronomically desirable but susceptible to P. coronata.

A series of drought years and the resultant dust storms in the northern Great Plains in the 1930's stimulated efforts to re-grass this area, where millions of acres of grassland had been plowed under and put into grain production to help meet the demand for food occasioned by World War I. Difficulty was experienced in obtaining stands of adapted grasses and it appeared that diseases were responsible, at least in part, for the failures to establish grass stands. Disease studies were initiated in this region, therefore, in cooperation with the Division of Cereal Crops and Diseases, the Division of Dry Land Agriculture, the Soil Conservation Service, and the North Dakota Agricultural Experiment Station.

The results of these studies were published in The Plant Disease Reporter in 1943 and 1946. It was shown that the main cause of the seedling blight of grasses in the Northern Great Plains is the fungus Pythium arrhenomanes Drechs. Certain other fungi, including Helminthosporium sativum Pam., King, & Bakke, Pythium debaryanum Hesse, P. ultimum Trow, P. irregulare Buis., and Fusarium scirpi Wollenw. var. acuminatum (Ell. & Ev.) Wr. were found to sometimes cause the grass seeds to rot in the ground and thereby reduce the stand.

In 1948, Gloeosporium bolleyi Sprague was reported to occur commonly on the roots of many species of grasses and cereals in the Western United States and proof was presented of its ability to cause seed rot and root necrosis.

Attempts to control pre-emergence seed rot and seedling blight by the use of such soil amendents as fertilizers and chemicals gave little encouragement, and seed treatments proved of little value except in inhibiting seed-borne fungi. It was observed that cool-temperature grasses, such as Russian wild rye, crested wheatgrass, and smooth brome, escaped seedling blight to a large extent if fall-seeded. The ability of certain of the fungi involved to persist in the soil for a period of years makes crop rotation of questionable value as a control measure.

Claviceps paspali F. L. Stevens & Hall, the fungus causing ergot of Paspalum spp., has been isolated in pure culture and the cultures have been used in inoculation tests to determine the reaction of various species of Paspalum to ergot. As a result of these tests, seven species of Paspalum were reported as new hosts of this fungus in 1939. On the other hand, the following species and strains were inoculated repeatedly but no infection resulted: P. notatum (narrow leaf type from Paraguay and common local type from Georgia), P. lividum, P. malacophyllum (a strain from Tifton, Georgia, and one from Gainesville, Florida), and P. intermedium. One of these species, P. malacophyllum, has been used by the grass breeders in crosses with dallis grass, P. dilatatum, in an attempt to secure a pasture grass of the dallis grass type that is immune or highly resistant to ergot.

Later studies in cooperation with the Georgia Agricultural Experiment Station and the Georgia Coastal Plain Experiment Station that were published in 1948 reported the susceptibility of Bahia grass (P. notatum) to C. paspali. These studies were initiated in 1941 when it was observed at Tifton, Georgia, that highly sterile Paraguay x common Bahia grass hybrids were much more heavily ergotized than either parent. Experiments made subsequently showed that when unpollinated panicles of Bahia grass were inoculated by immersion in a suspension of ergot conidia many ergot sclerotia developed. On the other hand, inoculating 30 minutes after pollination resulted in the production of only a few sclerotia, and florets inoculated 24 to 48 hours after

effective pollination developed no sclerotia whatsoever. It was concluded from these tests that effective pollination resulting in fertilization and seed set soon renders the florets of Bahia grass resistant to ergot attack.

In a comparison of 27 male sterile Bahia plants and a similar number of male fertile sister plants made in 1942, 33.1 percent of the male sterile florets but only 9.6 percent of the male fertile florets contained ergot sclerotia. Since the male sterile and male fertile plants should have been genetically the same, except for the male sterility factor, the differences in the amount of ergot produced by each must have been due to their differences in male sterility. These results suggest that in breeding for ergot resistance in grasses, care must be exercised lest differences in ergot readings due to sterility differences be mistaken for genetic differences.

Sclerotia of Claviceps paspali that had overwintered on the surface of the soil at Arlington, Virginia, were found capable of germination at any time during the following summer. It would appear, therefore, that infection can take place at any time during the summer that the Paspalum species are in flower. Many kinds of insects were observed to feed on the ergot "honey dew" and some of these insects were able to transmit the disease to healthy heads of dallis grass enclosed in celluloid cages in the greenhouse. It would appear from these observations and tests that insects play an important part in the dissemination of ergot of Paspalum.

In 1939, sclerotia of Claviceps yanagawaensis Togashi were found in seed of Japanese lawn grass, Zoysia japonica, imported from Japan. Since this fungus had not previously been reported from the United States, there appeared to be danger of introducing a new grass disease into this country. It was found that treating the seed containing ergot sclerotia with a 75 percent solution of sulphuric acid from 20 to 30 minutes killed the ergot sclerotia, whereas, the germination of the seed was improved by this treatment. It appears, therefore, that such treatment would provide an effective method of eradicating ergot sclerotia from imported grass seed.

A disease similar to ergot in that it affects only the seed of the grass plants and results in a lowered germination is the "blind seed" disease of perennial ryegrass that occurs in some sections of the Willamette Valley in Oregon. Intensive investigations of this disease have been in progress since 1943 in cooperation with the Oregon Agricultural Experiment Station and the results obtained in this study are summarized in a later section of this paper.

Approximately 200 species of fungi cause leafspots on grasses. Some of the more aggressive parasites occur in the genera Helminthosporium and Septoria and studies made to date have been largely restricted to these because of their greater economic importance. Reference has been made earlier in this paper to the fact that Helminthosporium sativum Pam., King & Bakke is one of the fungi causing pre-emergence seed rot and seedling blight of grasses in the northern Great Plains. Other Helminthosporium diseases that have been studied are the brown leaf spot of smooth brome grass and the leaf blight of Sudan grass.

Studies of the brown leaf spot of smooth brome grass (Bromus inermis) were undertaken in cooperation with the Wisconsin Agricultural Experiment Station in 1941 and the results of these studies were published in 1945. This disease is characterized by small, dark brown, scattered specks on the young leaf blades. A yellow halo develops around each spot and both spots and halos increase in size until coalescing lesions form large yellow patches on the leaf. Eventually, the entire leaf yellows and withers from the tip downward. The conidiophores of the causal fungus, Helminthosporium bromi Died. are produced on the brown spots or generally over the surface of the withered leaf. Conidial production, however, is extremely sparse and it was concluded from these studies that conidia play a minor role in the spread of the disease.

The ascigerous stage of the fungus develops in the infected leaves during the summer but mature ascospores are not produced until the following spring. The overwintered perithecia provide ascospores for the initial infections very early each spring and remain as sources of inoculum throughout the spring season. The ascigerous stage of the fungus was identified as Pyrenophora bromi Drechs.

Host range studies made during this investigation included six grasses and four cereals common to Wisconsin, but only smooth brome grass developed typical brown-spot symptoms and produced lesions from which the fungus could be reisolated. Inbred lines of this grass differed markedly in their reaction to brown spot. Some lines were completely susceptible, while others were highly resistant, indicating that breeding for disease resistance should provide an effective control. Attempts to isolate the causal fungus from seeds collected from the panicles of heavily infected plants were unsuccessful, and it was concluded that the fungus is not seed-borne.

Foliage diseases of Sudan grass (Sorghum vulgare var. sudanense) occur throughout the eastern half of the United States and in many years materially reduce the yield and quality of the forage. Leaf blight, caused by the fungus, Helminthosporium turcicum Pass., is one of the

most widespread and common of these disorders. The characteristic symptoms of leaf blight are large linear to irregular lesions on the leaf blades, often extending into the leaf sheaths. The lesions are first water-soaked, then light olivaceous to brown, and finally straw colored as the tissues dry out. Narrow bands of reddish-brown pigmentation often occur along the margins of the lesions. Conidia are produced abundantly on the older portions of the lesions and cause new infections. The floral bracts of Sudan grass are frequently infected and work at the U. S. Regional Pasture Research Laboratory showed that the fungus occurs in the seed and glumes of a high percentage of Sudan grass seed lots.

In addition to attacking Sudan grass, H. turcicum causes a serious leaf blight of corn and occurs also on sorghum and Johnson grass. The results of inoculation tests with cultures from these four hosts were reported in 1945 and demonstrated the existence of four distinct parasitic races of the fungus. Two cultures from common Sudan grass and one from Atlas sorghum were pathogenic on Sudan grass and Gooseneck sorghum, but all three failed to infect corn. Four cultures from corn infected common Sudan, while two did not, but all six were highly pathogenic on corn. The culture from Johnson grass caused heavy infection only on Johnson grass.

Since the susceptibility of Sudan grass to foliage diseases was recognized as a limiting factor in its production in the warm, humid regions along the South Atlantic and Gulf coast, breeding for disease resistance was one of the principal objectives in a program of Sudan grass improvement undertaken in 1936 in cooperation with the Georgia Coastal Plain Experiment Station and the Georgia Agricultural Experiment Station. In that year, a number of selections and commercial varieties of Sudan grass from the Middle West were grown at Tifton, Georgia, for comparison with common Sudan. All seemed equally susceptible to foliage diseases but Leoti sorghum which was included in this nursery proved to be highly resistant. A number of hybrids were made, therefore, between the most desirable types of Sudan grass and the disease-resistant Leoti sorghum.

The F₁ plants of these hybrids were grown in the greenhouse the following winter and enough seed was obtained to grow approximately 35,000 F₂ plants in the field in 1937. Six coarse-stemmed plants which seemed to possess the disease resistance of the Leoti parent were selected from this population and were back-crossed to some of the best individuals in a Sudan selection nursery in order to obtain a finer stemmed grass more like Sudan. These backcrossed hybrids were grown in the greenhouse the following winter and enough seed was obtained to grow approximately 30,000 F₂ plants in the field in 1938. Only one individual was found in this planting which possessed the disease resistance of the Leoti parent and the vegetative characters of Sudan grass.

This resistant plant was moved to the greenhouse and there produced enough selfed seed to permit planting a 500-plant progeny test in the field in 1939. Study of this progeny revealed that this selection was breeding reasonably true for both disease resistance and the vegetative characteristics of Sudan grass. An isolated seed-increase block of this strain was planted at Tifton, Georgia, in 1940, but the very low seed yield obtained demonstrated the desirability of increasing the seed supply in one of the southwestern States producing Sudan grass seed. Arrangements were made, therefore, to increase the seed of this new strain at Lubbock, Texas, and 2,200 pounds of recleaned seed were produced at this location in 1941. The new strain was given the name Tift Sudan and the Texas-grown seed was distributed for widespread testing in 1942.

These tests showed that throughout the Eastern United States, Tift Sudan is much more resistant to leaf blight than are the other strains of Sudan grass. It also possesses resistance to anthracnose, caused by Colletotrichum graminicolum (Ces.) G. W. Wils., and to two bacterial foliage diseases (stripe and streak).

Studies reported in 1944 showed that it is subject to attack by a previously unreported species of Helminthosporium that causes a leaf spot on Tift Sudan quite similar in appearance to that caused by H. maydis Nisikado and Miyake on corn. In 1948, this disease was given the common name of "target spot" and the causal fungus was described and named Helminthosporium sorghicola Lefebvre & Sherwin. So far, the new disease has not affected field plantings of Tift Sudan seriously and this grass has been accepted generally as a superior new variety in the eastern United States. It is also being used as disease-resistant parent in attempts to further improve Sudan grass in most State experiment stations where Sudan grass breeding programs are underway.

Cooperative work on Sudan grass improvement between the Texas Agricultural Experiment Station and the Bureau resulted also in a successful combination of the desirable characters of Sudan grass and those of the sweet sorghum variety Leoti. By crossing, backcrossing to Sudan,

and selecting over a period of years, a variety named Sweet Sudan was developed. This new variety possesses the sweet and juicy stem, the distinctive sienna glume color, and the resistance to shattering of the Leoti parent combined with the growth habit and production of common Sudan grass. Since this selection was made in a drier climate where foliage diseases are not as severe as in the Southeastern United States, Sweet Sudan is not as resistant to these diseases as is Tift. Breeding is being continued, therefore, for improvement in the resistance of Sweet Sudan to foliage diseases. A combination of the many desirable characteristics of Sweet Sudan with the disease resistance of Tift should provide a variety of Sudan grass much superior to any now being grown.

In 1947, as a result of the cooperative work with the Division of Cereal Crops and Diseases and the Mississippi Agricultural Experiment Station, a leaf spot of corn, sorghum, Sudan grass, and Pearl millet (*Pennisetum glaucum*) that occurs in the Southern United States was described and the causal fungus was identified as *Helminthosporium rostratum* Drechs. This appears to be primarily a disease of corn and Pearl millet since none of the sorghums or sorghum relatives tested were very susceptible.

Numerous species of *Septoria* cause blotches on the leaves of cereals and grasses and sometimes cause defoliation and reduce seed yield. The irregular blotches are straw-colored to brown and bear dark-brown to black pycnidia on the older portions of the lesions. The conidia (pycnospores) borne in these structures are predominantly at least ten times as long as broad, are hyaline to chlorinous, nonseptate to multiseptate, straight to curved, and are fusiform, filiform, or scolecosporous in shape. A detailed description of many of the species and varieties of *Septoria* that attack grains and grasses in the Western United States was published in 1944 as a result of studies of their life history and taxonomy made in cooperation with the Division of Cereal Crops and Diseases and the Oregon and Washington Agricultural Experiment Stations.

In 1940, during the course of the above studies, those species with nonseptate, falcate pycnospores borne in small globose pycnidia were transferred to the genus *Selenophoma*. The more important grass parasites placed in this genus are *Selenophoma bromigena* (Sacc.) Sprague & A. G. Johnson which causes leaf blotch of smooth brome grass, and *S. donacis* (Pass.) Sprague & A. G. Johnson which attacks *Arundo donax* and a number of other grass species. In 1943, the *Septoria*-like types on grasses with broader pycnospores that are multiseptate and yellowish-brown to light-brown in color were transferred to the genus *Phaeoseptoria*. The fungi placed in this genus occurred in most cases on languishing leaves of various grasses and appeared to be semi-saprophytes of little economic importance. These studies have provided new information on a considerable number of grass parasites and have emphasized the complexity of the group of pycnidium-forming fungi that cause spots or blotches on the leaves of grasses.

TURF DISEASE INVESTIGATIONS

Studies of turf diseases and their control have been conducted by the Division in cooperation with the United States Golf Association Green Section over a period of approximately 20 years. Three types of control measures have been investigated: (1) the use of disease-resistant strains of grasses; (2) the employment of correct cultural practices; and (3) the use of fungicides.

The results of these investigations were published in The Bulletin of the United States Golf Association Green Section for August 1932. This publication has been of great value to greenkeepers and others responsible for the maintenance of turf.

Most of the experimental work on turf disease control was conducted on the plots making up the turf garden at the Bureau's Arlington Experiment Farm prior to the entry of the United States into World War II. With the abandonment of the Farm for agricultural purposes at that time, intensive work on turf diseases was terminated and has not since been resumed. Considering the vast sums that are expended annually on the establishment and maintenance of lawns around homes and public buildings, in parks and cemeteries, on playing fields and golf courses, on airfields and military installations, and along roadsides, it seems that more adequate public support for the investigation of control measures for turf diseases would be justified.

BLIND SEED DISEASE OF PERENNIAL RYEGRASS

A history of the work done on the blind seed disease since its presence in the United States was first recognized in 1943 is presented as a separate section of this paper, since it is felt that it illustrates very well an instance in which forage crops disease investigations have been

of immediate practical value to growers. Such instances are not numerous in this field of work, since in most cases control must be sought through the development of a disease-resistant variety in cooperation with a forage breeder. As a rule, approximately ten years are required to reach such a goal and sometimes it requires nearly 20 years.

Low germination of the seed of perennial ryegrass, Lolium perenne, produced in sections of the Willamette Valley in Oregon was first noted in 1941. More extensive difficulties were experienced in 1942 while in 1943 approximately one-fourth of the seed crop could not be certified because of less than 85 percent germination and it appeared that commercial seed production of this grass in the area was doomed. During the winter of 1943, it was established that the difficulty was due to the blind seed disease caused by the fungus Phialea temulenta Prill. & Delacr. and studies were undertaken in cooperation with the Oregon Agricultural Experiment Station. This disease had been shown previously to be responsible for low germination of the seed of perennial ryegrass in New Zealand, Ireland, and Scotland.

The seed is the only part of the plant infected by this fungus, which overwinters in infected seed that has fallen on the ground. Apothecia are produced in the spring coincident with the flowering of the grass and the ascospores produced in these fruiting structures initiate the primary infections. Conidia are produced abundantly in a slimy matrix on infected seeds during the spring and spread the infection to additional flowers, thus producing an epidemic.

The first apothecia of this fungus ever seen in the United States were found in Linn County, Oregon, in May 1944. Apothecia have been found in abundance since then on seeds of perennial ryegrass and darnel (L. temulentum), and on a few old seeds of Hordeum gussoneanum.

Workers in New Zealand had reported that no apothecia were obtained from two-year-old seed, and based on this information, the planting of such seed was recommended to Oregon growers during the winter of 1943. While the planting of aged seed, or of disease-free seed, is an excellent control measure, it cannot provide more than partial control when the disease is left unchecked in nearby fields, because of the natural spread of the disease by ascospores.

A service for growers of ryegrass seed in New Zealand provides for examining head samples for infestation before harvest to enable the growers to avoid the expense of harvesting worthless seed crops. A modification of the New Zealand method of pre-harvest testing was tried in Oregon on a rather extensive scale in the summer of 1944. While this method was found to give reliable estimates of field infestation, it did not appear to be of much value to growers in Oregon, since perennial ryegrass is grown extensively in that State in pure stand and primarily for a seed crop. In New Zealand, on the other hand, white clover and perennial ryegrass usually are grown in pasture mixtures, and if the ryegrass seed crop is found badly diseased in pre-harvest tests, the grower may either cut the field for hay or save it for a later clover seed crop. His loss is, therefore, comparatively light when compared with that suffered by an Oregon seed grower. Further, there is an apparent weakness in this system in that it leaves heavily infested fields as sources of abundant inoculum for reinfestation of old fields and possible infestation of new fields.

Pre-harvest testing of head samples was discontinued in Oregon, therefore, after one season's trial and was replaced by a seed testing service. Seed samples from every perennial ryegrass seed production field in Oregon that had been entered for certification were examined for the presence of the conidia of the blind seed fungus during the winter of 1944. In making the examinations, glass vials of approximately 18 ml. capacity were used to measure the seed which was placed with the same amount of water into a 250 ml. Erlenmeyer flask. After soaking for 20 minutes, the water was strained from the seeds and a drop of the suspension was placed on a microscope slide for a conidial count. A Bausch and Lomb haemocytometer with Neubauer ruling was used to standardize the method. After making numerous conidial counts and comparing the results with the germination of the respective seed samples, eight classes of infection were set up to classify individual samples.

The degree of infection in seed samples that would result in a germination below 85 percent in the next crop was estimated to be the Light class of infection, i. e., those having 7 to 15 conidia per 1/160 cu. mm. If the seed samples showed this amount, or a heavier infestation, the fields were regarded as unprofitable for another year and it was recommended to the grower that such fields be plowed before May 1, 1945, since apothecial production was known to begin early in May. This recommendation was rather generally followed after it was explained to the growers that they would profit by cleaning up such fields and returning them to production and that leaving such infested fields would constitute serious hazards to neighboring fields that were still producing good seed.

Fields whose seed samples revealed a Very Light class of infection, i. e., those having 4 to 6 conidia per 1/160 cu. mm., were regarded at first as probably safe for another year's seed

production. Experience soon revealed, however, that fields with a Very Light infestation were likely to produce seed of poor germinability, if the field were poorly drained and likely to be wet in May and early June. It was, therefore, recommended that such fields also be plowed.

During the years this program of disease control has been in operation, there has been a gradual elimination of diseased fields, and an increase in fields without any blind seed disease. It appears that if the growers will continue to cooperate in this program, the disease may be practically eliminated as a limiting factor in perennial ryegrass seed production in Oregon.

BROWN STEM ROT OF SOYBEAN

Although only a few soybean fields infected with brown stem rot were observed in Central Illinois in the fall of 1944, this disease occurred in severe epidemic form in Central Indiana, Illinois, and Iowa in 1945. Complete loss of yield occurred in some fields and damage in some entire counties in Central Illinois was estimated as 10 percent. The disease is now recognized as one of the most important diseases of the soybean crop throughout Illinois and is becoming increasingly important in Indiana, Iowa, Missouri, and Ohio.

The first symptom of brown stem rot usually appears in July or early August. At this time infected plants show no external evidence of the disease, but if the stems are split longitudinally a brown coloration of the pith and vascular elements is observed extending upward from the base of the stem. In seasons which are unfavorable for the development of the disease, only the internal stem symptoms occur. Under conditions favorable for disease development, a sudden blighting and drying of the leaves occurs in late August or early September. The leaf tissues adjacent to the veins remain green while the interveinal portions die. As a result of the extensive blighting of the leaves, a badly infected field appears brown from a distance as contrasted with the yellow-green of a normally maturing field. In advanced stages the outside of the stem turns brown and the plants lodge badly because of the extensive internal rotting. It is the lodging of the plants and the resultant mechanical difficulties in harvesting that are responsible for the substantial losses caused by this disease. Weather conditions at harvest time, therefore, are of extreme importance in determining the amount of loss that occurs.

A fungus that produced a dense, putty-colored, non-fruiting mycelial growth on culture media was readily isolated from the diseased plants and was proved by inoculation tests to be the cause of the diseased condition. Since the fungus did not produce a spore-bearing stage on the diseased soybean plants and no fruiting was observed on culture media, identification of the causal organism was impossible. Studies were undertaken, therefore, on methods for inducing sporulation by this fungus.

The results of these studies, conducted in cooperation with the Division of Cotton and Other Fiber Crops and Diseases and the Mississippi Agricultural Experiment Station, were published in 1947. In this work it was found that the fungus produced conidia sparsely on potato-dextrose agar, oatmeal agar, and potato-dextrose-raisin agar and that the spores could be suspended readily in sterile water by gently flooding the surface of a two-month-old culture. These spores germinated readily when planted on 2 percent water agar and conidiophores and conidia were produced abundantly in 8 to 10 days at room temperature. Cultures younger than two months were induced to fruit also by dividing a small portion of the mycelial mat very finely and placing the fragments on water agar. From the characteristics of the conidiophores and conidia, the fungus was identified as a species of *Cephalosporium*.

More detailed studies of this fungus and the disease have been conducted at the U. S. Regional Soybean Laboratory in cooperation with the Illinois Agricultural Experiment Station. The results of these studies were published in 1948. In this work, a large number of vegetable decoctions in 2 percent agar and with and without dextrose, were tested as media for inducing sporulation.

Conidia were produced on string-bean agar, rice polish agar, cucumber agar, and soybean-stem agar. The addition of 2 percent dextrose to the above media inhibited sporulation. Spore production was best on the soybean-stem agar, the spores appearing after five days at 20° C. Spore germination studies showed that the optimum temperature range for germination was 21° to 25° C.

Since the fungus *Cephalosporium acremonium* Cda. had been reported in 1924 to produce a systemic infection of corn in the Midwest that was characterized by blackened vascular bundles in the corn stem, the brown stem rot fungus of soybean was compared very closely with it. Cultural and morphological differences between the two fungi were immediately evident and cross inoculation tests showed that the two were pathologically distinct. Since the brown stem rot fungus did not seem to conform to the description of any species of *Cephalosporium* previously published, it was concluded that it was a new species and the name *C. gregatum* Allington &

Chamberlain was proposed. This specific name was suggested by the most outstanding characteristic of the fungus in culture, i. e., the aggregates of short, straight or club-shaped conidiophores.

Attempts to isolate the causal fungus from seed harvested from diseased plants have all been unsuccessful, indicating that it is not seed-borne. It has been demonstrated, however, that the fungus can exist for more than a year in moist soil stored in the greenhouse. Further, plants grown in naturally infested soil under the proper environmental conditions readily become infected and thereby supply a reliable criterion for the existence of the parasite in the soil. It appears that in the field, therefore, the roots are the most common points of entry and that the fungus progresses from the roots upward through the water-conducting vessels of the stem, lateral branches, and petioles.

The effect of soil and air temperature on the incidence and development of the disease were studied in the greenhouse. While the disease did not appear to be particularly responsive to different soil temperatures in these tests, the response to air temperatures was quite striking. When inoculated plants were grown at an air temperature of 15° C., the internal browning of the stems was evident 8 to 10 inches above the point of inoculation and typical leaf symptoms of the disease were observed within two or three weeks. At 21° C., on the other hand, progress of the infection was almost inhibited and at 27° C., no spread of the fungus in the plants was observed. These results offer an explanation of why the disease develops very slowly under the high temperature conditions of mid-summer, then develops with great rapidity with the occurrence of a few cool days and nights in the autumn.

In limited host range studies, soybeans and the mung bean (*Phaseolus aureus*) were the only plant species shown to be susceptible to attack by the brown stem rot fungus.

In September 1946, an aerial survey was made to locate brown stem rot-infested soybean fields in Central Illinois. The overall brown color caused by the dead leaves in the later stages of the disease contrasts sharply with the yellow-green of normally maturing fields, thus making identification by aerial observation possible. From the air it was observed that certain fields were only partly diseased and that a sharp line of demarcation separated the diseased and healthy portions of such fields. These fields were located on a detailed map while in the airplane and the farms were visited later by car. On these visits the diagnosis of brown stem rot was verified and the farmer was interviewed in regard to the history of the diseased and healthy portions of his field.

Within a period of two weeks, 35 such fields were investigated and completely reliable histories were available on 15 of these fields for a period of at least four years. Without exception, the information gained by this method indicated a crop rotation effect upon the incidence of the disease. The diseased portions of fields were found to have had different crop histories from the healthy portions in that soybeans had been grown much more frequently in short rotations, such as corn-soybeans-corn-soybeans. On the other hand, a four-year rotation of corn, soybeans, oats, and clover appeared to have controlled the disease satisfactorily on the farms studied. On the basis of these studies, it was concluded that one method of controlling brown stem rot in Illinois is to practice a crop rotation system which provides for three successive annual crops other than soybeans between soybean plantings. Studies in 1947 and 1948 have confirmed the value of four-year rotations in lessening the severity of the disease and reducing the losses suffered.

While crop rotation has been shown to be an effective method of controlling the brown stem rot disease in Central Illinois, it does not provide complete control nor offer a method of eradicating the causal fungus from the area. Intensive search is being made, therefore, for strains of soybeans that are resistant to the brown stem rot fungus.

Since no satisfactory method for the mass inoculation of soybean field plantings with brown stem rot has been developed, natural infection must be depended on in testing for resistance to this disease. In 1947 and again in 1948, therefore, a farm field near Weldon, Illinois, where the soil is known to be infested with the brown stem rot fungus, has been used for growing an extensive soybean nursery in the search for resistance to this disease.

The 1948 nursery consisting of 1450 soybean introductions and varieties was planted at Weldon in May and disease ratings based on the density and height of internal browning in the stem were assigned in September. These ratings were made on a scale of 0 to 5, with 0 indicating no browning and 5 indicating dense browning throughout the stem. While all of this plant material was susceptible to the disease in some degree, differences in the extent and intensity of the browning were observed. Eleven of the soybean introductions showed only traces of browning (numerical rating 1), while many more showed light infection.

Further testing of this material in similar trials will be necessary to more fully evaluate

its resistance to the disease. It appears from the results to date, however, that within a few years strains of soybeans resistant to brown stem rot will be available to the soybean breeders for use in crosses. The object of these crosses will be the development of new, superior soybean varieties that will be resistant to the brown stem rot disease, thus providing a method of control far superior in many respects to the rotation practices now recommended for holding this disease in check.

SUMMARY

The plant disease research on forage crops conducted by pathologists of the Bureau of Plant Industry, Soils, and Agricultural Engineering over a period of approximately 35 years is summarized under the following sub-divisions: (1) Alfalfa; (2) Clovers; (3) Soybeans; (4) Lespedeza, Cowpea, and Miscellaneous Legumes; (5) Hay and Pasture Grasses, and (6) Turf.

Two forage diseases, i. e., the blind seed disease of perennial ryegrass and the brown stem rot of soybean, are given more detailed consideration in separate sections of the paper since they provide typical examples of current problems and the methods of investigation being employed.

The work summarized concerns 12 diseases of alfalfa, 13 diseases of clover, 9 diseases of soybean, 3 diseases of annual lespedeza, 3 diseases of cowpea, 5 diseases of Austrian winter pea, 3 diseases of vetch, 2 diseases of kudzu, 7 diseases of lupine, and 24 diseases of hay and pasture grasses. No specific diseases of turf grasses are mentioned in the brief summary presented of the cooperative work in this field.

The research work on forage crops diseases has been conducted in large part in cooperation with one or more of the State agricultural experiment stations, or other agencies, and such cooperation is recognized throughout the paper. This cooperation has frequently involved grass and legume breeders as well as forage pathologists, since control of most forage crops diseases must be sought in the development of disease-resistant varieties of the crops.

DIVISION OF FORAGE CROPS AND DISEASES

PLANT PATHOLOGY IN THE DIVISION OF RUBBER PLANT INVESTIGATIONS ✕

J. B. Carpenter¹

INTRODUCTION

History of the Division

The United States Department of Agriculture first expressed an interest in rubber-bearing plants about 1890 through its plant introduction activities. The first appropriation specifically for investigation of sources of rubber was an allotment of funds from a Commerce Department appropriation in 1923. This and the following annual appropriations (made directly to the Department of Agriculture) were assigned to the Division of Crop Acclimatization and Adaptation Investigations which later was renamed the Division of Cotton, Rubber, and Other Tropical Plants. In 1934, the rubber work was reassigned to the Division of Plant Exploration and Introduction. In 1940, a greatly expanded project for encouraging rubber production in the Western Hemisphere was authorized and placed tentatively under the administrative direction of the head of the Division of Sugar Plant Investigations. This project developed rubber investigations in cooperation with 14 Latin American countries. In 1942, this latter project and the work previously assigned to the Division of Plant Exploration and Introduction were combined into the present Division of Rubber Plant Investigations.

Program

The work of the Division proceeded along two parallel courses. The first of these was concerned only with studies on species of Hevea, principally H. brasiliensis (H. B. K.) Muell. Arg.; the second was concerned with the investigation of alternative, domestic rubber-bearing plants, both to supplement the production of rubber of the Hevea type, and to find, if possible, special purpose rubbers. The latter studies were centered primarily on guayule, Parthenium argenteum Gray, with attention also to the possibilities of the Russian dandelion, Taraxacum kok-saghyz Rodin, and goldenrod, Solidago spp.

Early Investigations

The earlier publications of the Department dealt mostly with taxonomic and production problems of rubber-bearing plants and it was not until 1923 that any important disease investigations were made. In that year, a survey was made of the South American Leaf Blight of Hevea rubbertrees caused by Dothidella ulei P. Henn. in certain Caribbean countries, and in the same year an extensive survey of the diseases of the Hevea rubbertree in the Amazon Valley was begun. About 10 years later, the scab disease of goldenrod, caused by Elsinoë solidaginis Jenkins & Ukkelberger, was the subject of investigations in the Southeastern United States, where it had assumed great severity on both the indigenous species and the selections under trial for rubber production.

SOUTH AMERICAN LEAF BLIGHT

Introduction

Disease Characteristics and Economic Importance: -- Concurrent with the increased interest in rubber production beginning in 1940, pathological problems immediately presented themselves as the several cooperative field stations were developed. The most important problems centered on the control of the South American Leaf Blight, which weakens and may kill plants of all ages through repeated defoliations, reduction of leaf surface, and cankering of young stems and petioles, with less frequent attacks on fruit pods and inflorescences. This disease had, up until the early 1940's, been a major factor in the failure to establish successful large-scale plantings of Hevea in tropical America. In British and Dutch Guiana and Trinidad, leaf blight destroyed thousands of acres of Hevea rubbertrees from 1910 to 1920, and later rubber-growing enterprises in Brazil, Panama, and Costa Rica were seriously handicapped by the ravages of the disease.

¹Editor: Prepared cooperatively by the staff of the Division.

First Disease Surveys: -- The Department's surveys of this disease, begun in 1923, established its great economic importance as a limiting factor in the successful development of rubber plantings at that time, and its potentialities as a formidable pathological problem should the plantation industry be expanded in tropical America. These surveys gave a detailed report on the incidence of the disease in the countries visited--British and Dutch Guiana, Trinidad, Brazil, Bolivia, and Peru--and brought together for the first time all of the pertinent literature on leaf blight and its causal organism.

Recommendations for Disease Control: -- Methods for controlling the disease were considered in the survey reports, and the two principal recommendations, complemented later by the development of fungicidal control measures, became the basis for the control program when the rubber investigations group was organized almost two decades later. These recommendations were (1) the selection and development of disease-resistant types of *Hevea*, to be propagated vegetatively as clones, and (2) the strict enforcement of quarantine regulations on the movement of propagating stocks, either internally or internationally.

Thus, by 1940, the approach to the control of leaf blight had been established, although only partially developed. The protection of nursery and propagating stocks was a matter of great importance and urgency, which was met by the development of adequate fungicidal measures for spraying or dusting nurseries. At the same time, the selection and development of disease-resistant clones was undertaken and greatly facilitated by the cooperation of the Ford Plantations Company and the Goodyear Plantations Company, both of which had had such work in progress for many years. In addition to varying national quarantine requirements, the Department's representatives established and maintained strict procedures governing the shipment of propagating stocks.

Cultural Practices in Relation to Control: -- A brief consideration of the horticultural practices involved in rubber production is pertinent here to explain the procedures used in the control of leaf blight. High-yielding *Hevea* clones are propagated by bud-grafting them onto one-year-old seedlings. Thus, a young tree commonly consists of a seedling root stock with the above-ground part produced from a low budding. In the absence of clones that combine high yield with high blight resistance, the budding process may be carried one step further. Seedlings budded with a high-yielding, blight-susceptible clone may be top-budded with a blight-resistant clone at a height of approximately six feet, a procedure made feasible because the yield of a tree is determined largely by the trunk or tapping-panel clone. The double-budding operation offers a real advantage as it permits selection of the tapping-panel clone almost solely on the basis of yield, whereas the crown clone may be chosen on the basis of resistance to disease and insect pests, and resistance to wind damage.

Fungicidal Control

Methods and Materials: -- Turning to a consideration of the fungicidal control measures evolved, earlier sporadic spraying experiments were unsuccessful. However, equipment and materials for a thorough investigation of the subject of fungicidal control of leaf blight were assembled soon after the program of rubber investigations was launched in July 1940. In October of that year, spraying and dusting experiments were started in young seedling nurseries on the Goodyear Rubber Plantation in Panama. During previous years, more than 90 percent of the seedlings planted in some of the nurseries there had been destroyed by leaf blight.

The spraying tests in Panama were conducted under hot moist conditions that induced constant emergence of young susceptible foliage and frequent infection periods for leaf blight. This allowed little opportunity for unprotected plants to escape the disease; therefore, the results of these tests were soon obvious, and they have proved to be reliable.

Tests with various types of spray equipment have shown that power-driven pumps are most efficient for spraying large nurseries. However, in the case of young plants growing at field spacing, knapsack sprayers are the most efficient type.

Copper Fungicides: -- Bordeaux mixture, prepared according to a number of formulae, was used in the first spraying tests. It gave excellent blight control, but often injured very young plants. High-lime Bordeaux caused more injury than low-lime Bordeaux. The "insoluble" copper fungicides, proprietary products sold under a number of trade names, gave excellent disease control without injuring young plants. Subsequently, spray mixtures containing 2 pounds of "insoluble" copper fungicide and a small amount of spreader and sticker per 100 gallons of water have been used to protect millions of disease-susceptible seedlings growing in nurseries from Mexico to Brazil and Peru. Sprays applied at a maximum frequency of once or twice per week have frequently controlled leaf blight.

Sulfur and Organic Fungicides: -- Lime-sulfur, when used at concentrations high enough to control the disease, burned Hevea leaves during periods of bright hot weather. Colloidal and dry-wettable sulfurs caused little or no damage to Hevea foliage but were less effective than "insoluble" copper fungicides in controlling leaf blight.

In addition to the older copper and sulfur fungicides, a variety of new organic materials were used in these experiments. Some of the organic fungicides were less effective than colloidal sulfur, whereas others were almost as effective as the "insoluble" copper fungicides.

Spreaders and Stickers: -- Preliminary trials indicated that spreaders and stickers, such as rosin, casein, flour, oils, and a number of proprietary products, were essential for the deposition and retention of the fungicides, in view of the waxy nature of Hevea foliage and the frequency of tropical rains. Spreaders and stickers generally improved disease control, but the oils caused severe stunting of plant growth. Rosin and casein preparations gave the most satisfactory results.

Dusting: -- Both copper and sulfur dusts gave partial disease control. The degree of control, however, was less than that obtained by spraying with similar fungicides.

Influence of Fungicides on Budding Success: -- Recent studies have shown that the choice of fungicides may influence budding success. When copper fungicides are applied frequently to budwood gardens, the bud patches derived from those plants may give low budding success, through some deleterious effect of the fungicidal residues. This effect, however, can be largely eliminated by washing with water prior to removing the bud patches. For this reason, it has been recommended that certain effective organic fungicides be used for budwood gardens. Within the last few months, investigations on the Diplodia disease of bud grafts in Mexico have indicated that the same organic fungicides are the most effective in preventing this disease, thereby giving further impetus to the use of these materials for general nursery spraying.

Control in Relation to Cultural Practices: -- Success in controlling leaf blight by spraying seedling nurseries encouraged tests in spraying high-yielding, blight-susceptible clones until they reached top-budding size. After seedlings are budded with blight-susceptible clones, they may be transplanted to the field immediately or they may be grown under spray in the nursery until they are top-budded. The more desirable procedure will depend upon local conditions, especially favorable soil and rainfall, to insure survival of transplanted top-budded stumps.

In many localities, young susceptible budded plants growing at field spacing are not severely attacked by leaf blight during the first year (required for reaching top-budding size) and need no protection from sprays. In other localities, weekly or more frequent spray applications may be necessary. Even with this number of applications, spraying is a cheap protection because only the young susceptible leaves need be sprayed and, of course, all spraying is discontinued after the trees are top-budded with resistant clones.

From the beginning, blight control by spraying large plantation trees was not considered economical. Spraying, however, does have still another practical application in protecting high-yielding, blight-susceptible clones growing in mixtures with highly resistant clones in breeding gardens. The feasibility of preserving valuable breeding trees by spraying with fungicides was demonstrated by tests conducted in Panama.

Disease Resistance

Methods and Materials: -- Studies on disease resistance were initiated concurrently with tests on fungicidal control of leaf blight. This phase of the program was greatly facilitated by the pioneer selection and breeding work of the Ford and Goodyear Companies. An intensive search for high-yielding blight-resistant jungle trees was begun, and the program of crossing high-yielding Oriental clones with blight-resistant indigenous selections was augmented by personnel working under the intergovernmental agreements, whereby this Government and the cooperating Latin American Republics arranged for the interchange and testing of propagating materials for mutual benefit.

Several hundred clones showing high resistance to leaf blight have been selected after intensive resistance tests at Turrialba. These clones originated from the highest yielding seedling trees on the Ford Plantations, outstanding jungle trees, and special seed collections from widely separated parts of the Amazon Valley. In addition, the number of blight-resistant selections has been increased constantly by an extensive breeding program.

Prior to the development of adequate resistance testing, thousands of acres of susceptible and slightly resistant Hevea trees were planted at field spacing in or near blight-infested areas. Many of these plantings grew well for two, three, or four years before they were destroyed by

increasingly severe attacks of leaf blight. This resulted from increasingly favorable conditions for development and spread of the disease, brought about by the development of the trees from slender, unbranched stems to many-branched, interlacing crowns. To prevent the recurrence of these destructive attacks, a method for testing and selecting clones was developed, using testing plots which provided near-optimum conditions for blight development at the Cooperative Rubber Plant Field Station at Turrialba, Costa Rica. A study of the means of spread and behavior of leaf blight contributed to this work.

Resistance Testing Methods: -- The main disease-testing center was developed at Turrialba, located in a valley 2,000 feet above sea level and subject to frequent mists and heavy night dews. On most nights during the year, *Hevea* foliage remains wet at least 10 hours, which is long enough for blight spores to germinate and infect the young foliage of susceptible plants. The tests consisted of growing heavily-diseased seedlings in alternate nursery beds with the clones and selections to be tested for resistance, thereby subjecting them to a constant and abundant inoculum. This combination of conditions allowed little opportunity for disease escape, and observations on a large number of clones have shown that the damage sustained by plants growing in the Turrialba plot for six or eight months is comparable to the heaviest damage suffered by the same clones growing to maturity in dense plantation stands.

Classification of Selections: -- An interesting aspect of the disease-resistance studies was the development of a practical system of classifying *Hevea* clones for resistance, enabling trained technicians to make independent, uniform observations. Disease resistance may be exhibited either as resistance to leaf damage and defoliation, or as partial to complete inhibition of fungus sporulation. The second character is fully as consistent as the first, and much evidence shows that it should receive equal or even greater weight in selecting plants for resistance. Under the testing conditions explained above, maximum opportunities are given for infection. Being a long-term crop, *Hevea* rubber must be sufficiently resistant to withstand leaf blight under environmental conditions most favorable for disease such as occur in constantly growing and changing field plantings over a period of many years. The severest disease damage induced on plants growing in test plots is therefore accepted as the most reliable measure in predicting the long-term behavior of a clone.

The system of classification provides 10 classes for leaf damage and defoliation, and 5 classes for sporulation. As an aid to visualizing the system as a whole, the resistance classes may be grouped as follows: classes 1 and 2 are composed of practically immune clones; classes 3 to 6 are characterized by necrotic lesions and damage in ascending order; classes 7 and 8 show defoliation; and classes 9 and 10, dieback and death. In general, clones receiving low susceptibility ratings show little or no sporulation, whereas those with high susceptibility ratings show moderate or heavy sporulation. None of the class 1 and 2 plants studied has shown any sporulation, and all class 9 and 10 plants have shown heavy sporulation. Clones falling into classes 3 to 8, however, have not been so consistent, and certain clones in classes 4 or 5 have shown heavier sporulation than some in class 7 or 8. Each clone, therefore, receives a separate rating for resistance to damage and degree of sporulation.

Clones that have received disease ratings of 1 to 5, which bear non-sporulating to sparsely sporulating lesions, are considered entirely safe for use in field plantings. Clones that have similar ratings for sporulation but have fallen into classes 6, 7, and possibly 8, may be used in mixed plantings with more resistant clones. Regardless of the rating for resistance to leaf damage, clones showing heavy sporulation should not be used in field plantings and those with even moderate sporulation should be used sparingly, if at all.

Regional Tests on Variability of the Fungus: -- Considering the sensitivity of the fungus to weather conditions, together with regional variation in disease severity observed in plantings of the several cooperating countries, reliable selection work necessitated thorough resistance tests in more than one locality. Groups of clones from several widely separated areas of the native habitat of *Hevea* are being grown under comparable exposure to blight in regional test plots in Costa Rica, Panama, Trinidad, Brazil, and Peru. Likewise, large populations of *Hevea* seedlings from jungle trees are being tested at the place of their origin and in other areas. Both clones and seedlings that have proved highly susceptible in some areas have been damaged slightly or not at all in certain other areas. Prolonged exposure, however, has brought many cases of increased severity as variants of the fungus appear. Some clones have proved highly susceptible to certain variants only, and still others--now recommended for commercial use--have been highly resistant in all areas.

Results of the Resistance Studies: -- The use of thoroughly tested blight-resistant clones for top-budding high-yielding but susceptible Far Eastern clones has now become standard procedure. In blight-infested areas, fungicidal sprays are used to control the disease on

susceptible seedlings and Far Eastern clones until they are budded with resistant clones.

Following several years of study, it is now feasible, in some areas, to produce three-component trees (seedling rootstock, high-yielding panel, and disease-resistant top) on a nursery basis, distributing them thereafter for field plantings. This will be of great importance from the standpoint of disease control, as it will prolong the period that fungicides may be applied at reasonable cost and, in the case of leaf blight, will eliminate the possible need for field spraying. By maintaining the plants in a healthy, vigorous condition, the time required for completion of the double budding process is substantially shortened.

PELLICULARIA LEAF SPOT

The Pellicularia leaf spot disease of the Hevea rubber tree caused by Pellicularia filamentosa (Pat.) Rogers was first recognized in Brazil in 1943, and possibly a year earlier in Peru. In Brazil it had apparently been observed, though not recorded, some time prior to this and had been causing considerable damage. It has been reported once from Colombia and twice from Costa Rica, being a minor disease in both instances. During 1945, this disease assumed epiphytotic proportions in the Peruvian rubber plantings and a pathologist was assigned by the Division to Peru in 1946 to study the control and epidemiology of the disease.

Characteristics of the Disease: -- This disease is one of the "Rhizoctonia" leaf blights and initiates its attack on immature foliage, causing under favorable disease conditions severe defoliation of young plants. It may be a limiting factor in the production of propagating stocks if allowed to go uncontrolled.

Characteristically, the disease first appears on young expanding leaves as small cleared areas, on which appear few to many drops of exuded latex. Depending upon the clone, the latex may darken rapidly. If favorable disease conditions persist, within a few days the fungus begins to make a rapid radial superficial growth on the lower surface of the leaf, followed by discoloration of the older tissues and the production of more or less concentric rings, chalky to buff in color and temporarily interspersed with green tissue. Growing at a rate of several millimeters per day, the leaf spot or spots soon cause defoliation of the affected leaflets. The older portions of the lesion may bear an extensive sporulating surface, which appears as a silvery bloom.

Dry weather strongly inhibits the disease and the lesions are promptly delimited. Upon prolonged drying, the necrotic areas shatter, giving a shot-hole or ragged effect. In contrast to leaf blight, this is typically a debilitating and not a fatal disease.

Complementary Studies on Plant Growth: -- Detailed information on the growth of young rubber plants was sought to provide a basis for interpreting the results of control studies and information pertinent to the selection of disease-resistant clones. The development of the flush and its foliage was followed through several consecutive months in various studies. These showed that at Tingo Maria vigorous clonal or seedling plants produce a new flush about every six weeks, at least during the first year, and that the leaves of the flush require about three weeks to expand and assume their typical mature position. During the grand period of growth, the young leaf may elongate at an average rate of more than one millimeter per hour, with little difference in growth rate between night and day.

An eight-months study of artificial defoliation was also made, involving the removal of leaflets in multiples of 20 percent, to provide from no defoliation in the checks to complete defoliation in the most severe treatment. Young seedling trees were used and were protected by frequent spraying.

Production of Spores: -- Studies on the production and dissemination of basidiospores of the fungus led to the discovery that these are produced almost exclusively at night, beginning shortly after sunset. This mode of sporulation is so well developed that attempts to change the rhythmic production of spores by keeping the fungus in continuous light or darkness for prolonged periods failed to change its habits, though such treatments affected the quantitative production of spores. Inasmuch as the spores are freely discharged in enormous numbers, and considering the rate of spread of the disease, there can be little doubt that wind-borne inoculum is the chief means of dissemination.

Exploratory studies on the persistence of the fungus during prolonged periods indicate that it lives in refuse and soil, fruiting on damp surface debris. When conditions are favorable, the parasitic habit may be resumed.

Infection Studies: -- The time required for spore germination, infection, and incubation, and the period of susceptibility of the foliage were also examined. The data indicate that germination and infection occur in a few hours and that the lesions become apparent several days

later. The leaves are susceptible for only a few days. These studies were made in an improvised glass-roofed shelter to exclude rain and dew. Temperature and humidity were essentially the same as those prevailing outdoors.

Fungicidal Control: -- The development of control measures for protecting nursery and propagating stocks was of primary importance. Screening tests to determine the spraying, dusting, and phytotoxic properties of various fungicides and adjuvants began in June 1946 and beginning in October a comparison of ten spray and seven dust formulae was made over a four-months period.

It was found that weekly applications of sprays, carefully made, gave satisfactory control when insoluble copper, organic, or wettable sulfur fungicides were used. The better treatments reduced defoliation from about 40 percent to 2 percent or less, markedly reduced the incidence of infection, and caused most of the lesions that did develop to be delimited while small. The best dust treatment controlled leaf spot as well as the better sprays, but the other dust formulae were inferior, due principally to poor dusting qualities.

Disease Resistance: -- A *Pellicularia* disease-resistance trial area, similar to that described for leaf blight, was laid out in 1947 and the assembling of promising clones and selections begun. In addition to this, all of the nursery plantings in Peru were observed periodically, both the clone collections and the seedling populations, for possible disease-resistant individuals. The extensive collections of clones and seedling populations in Brazil were examined in 1948 and some breeding material was taken to Peru. To date, no resistant selections have been found in *Hevea brasiliensis*. *Hevea rigidifolia* (Spruce ex Benth.) Muell.-Arg., at present a non-commercial species with leathery foliage, appears to be highly resistant or immune. Fortunately, a few of the blight-resistant top-working clones are quite tolerant of the disease and make fair growth even under severe disease conditions.

Growth in Relation to Disease Control: -- Many years' observation of the disease by various investigators has led to the conclusion that the *Pellicularia* leaf spot is primarily a disease of nursery rubber plants, where it may seriously weaken the plants and render them unfit for rootstocks or clonal multiplication stocks. It also attacks the trees in the field until they begin to undergo annual leaf change at about three years of age. However, when leaf change begins, coinciding with the end of the dry season in Brazil and Peru where the disease is serious, the disease is at its lowest ebb and the new foliage is quickly formed and matured before infection can occur. Although some vigorous branches continue to make new, susceptible flushes throughout the year, the proportion of new foliage becomes progressively smaller so that by the third or fourth year after the onset of leaf change the disease becomes negligible.

OTHER PATHOLOGICAL INVESTIGATIONS

Other Disease Problems in Hevea Rubber: -- Other pathological problems associated with *Hevea* rubber culture are (1) the panel diseases which are important in areas coming into tapping; (2) the *Phytophthora* leaf, stem, and fruit disease which is an increasing problem in some areas; and (3) root disease which, though not serious at present, may be expected to increase in severity as the trees become older.

Diseases of Other Rubber-Bearing Plants: -- Pathological investigations on rubber-bearing plants other than *Hevea* have included intensive studies on certain diseases of guayule and the Russian dandelion. The most important groups of diseases on these crops are those caused by soil-borne fungi and include damping-off in seed-beds and root and crown rots associated with field plantings and stored propagating stocks. Foliage diseases and physiological disturbances have also received attention.

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DIVISION OF RUBBER PLANT INVESTIGATIONS

* PLANT PATHOLOGY IN RELATION TO FEDERAL DOMESTIC PLANT QUARANTINES *

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INTRODUCTION

The quarantine and regulatory field includes all those situations in the pest battle front where, in addition to individual effort, community cooperation, and technical aid and counsel, a control undertaking attempts to achieve more extensive or more certain accomplishment by taking advantage of the compulsions and restrictions obtainable only through the official legal powers of the State or Nation.

The quarantine field thus defined includes at times nursery inspection, tomato seed certification, and seed potato certification, as well as the more specific quarantine promulgations. All such projects have the common characteristic that in a greater or less degree the program makes use of special legal powers granted by either Congress or a State legislature. For this reason they assume a status somewhat different from that of the innumerable pest control efforts carried out voluntarily by the grower himself either on his own personal initiative or with valuable supplementary technical help and advice, an aid freely tendered but not of compulsory nature.

According to this viewpoint, quarantine and regulatory procedure cannot be regarded as an isolated undertaking, but simply as an additional means at the disposal of society in its constant and universal struggle against aggressive crop pests. It is available for use wherever it is obviously advantageous. It is most effective when it is combined and integrated with all the other measures devised to meet pest encroachment. In short, it constitutes another of the several elements in the general strategy of man versus pests, one more worth-while weapon against a common enemy. It thus fills a definitely useful place in the unity of human defense, along with all the other phases of the protective scheme.

RESEARCH RELATIONS

One of the most important relations of the regulatory field to plant pathology lies in the domain of research, since practically all successful attack on plant pathogens represents the translation of special scientific knowledge into field operations. Plant pathology is a relatively new science and regulatory efforts are a still more recent development. This means that the basic stockpile of scientific knowledge in this field is still far from complete. Not only is our fundamental accumulation scanty or lacking in many needed features, but also in its application a great many chinks and gaps remain to be filled in by supplemental investigation. All along the line there is urgent need for research.

Research is needed, in a fundamental sense, to bring into orderly perspective the still numerous unknown pathogens of the world; to establish clearly their host-ranges, climatic relations, life histories, and habits; their potentialities for crop damage; their means of dispersal; and the possibilities for their control. Basic research is thus as much a crying need for quarantine purposes as it is for ordinary control practices. It is gratifying to note the constantly increasing efforts now being devoted to broadening and perfecting the Nation's basic reservoir of knowledge on pathogens and their relations.

In addition to this slow and gradual increase in the general fund of available knowledge through patient research by innumerable students in a host of colleges and universities, experiment stations, industrial organizations, and governmental agencies, another type of research is needed in the quarantine field--special problem research. When a new and destructive crop pest appears on the scene a special research program is nearly always needed to discover quickly certain essential facts about the newcomer. Without these missing details quarantine or regulatory measures cannot be intelligently planned; in their absence costly mistakes and failures are possible; and in any case until these critical points are clearly resolved, action is likely to fall below its highest efficiency. Because time presses for solution these research efforts take on

¹While the writer has undertaken to assemble the information on the various subjects included in this review, he acknowledges with due gratitude the valuable assistance given by many colleagues in the Bureau of Entomology and Plant Quarantine and the Bureau of Plant Industry, Soils, and Agricultural Engineering, who have contributed most helpfully to its preparation.

the character of emergency projects. They have to be stripped to essentials--streamlined. The urgent time element also forces upon an administration all sorts of arrangements for the sake of expediency. Research units or individual workers are suddenly detached from less pressing problems and assigned to the new and urgent task; portions or phases of the problem are farmed out to centers where personnel and facilities exist, and funds must be secured from whatever sources are available.

In the domestic quarantine field most of the emergency research of this type in the plant pathological field has to be arranged with the Bureau of Plant Industry, Soils, and Agricultural Engineering or through State college and experiment station facilities. Research in disease problems cannot be undertaken directly by the quarantine administration, although in insect problems the existing Departmental organization permits a somewhat closer coordination between the quarantine and the research functions. In the early years of quarantine development considerable difficulty was encountered in providing for emergency research problems, largely because trained technical workers were not always available. With the greatly increased numbers of experienced plant pathologists now in State and Federal service, the possibility of arranging for prompt emergency research work is not nearly so difficult as it used to be.

A Division of Control Investigations has been set up in the Bureau of Entomology and Plant Quarantine to develop and perfect control procedures, largely in those phases of the regulatory field which can be solved in their mechanical, chemical, or operational aspects without extensive biological research.

A third and minor field of progress in knowledge concerns the numerous opportunities presented in the field operations of a quarantine or regulatory project for the study and improvement of important features of its own procedures. In the nature of things these needs must be recognized and evaluated by the workers themselves, and since they likewise possess the intimate knowledge necessary for planning and conducting studies on these difficulties, it seems natural that these project investigation problems should not be farmed out in other quarters, but should be solved as far as possible on the spot. The type of studies normally falling into this category would include investigations intended to improve inspection methods, to work out cheaper, simpler, or more effective treatments, to lighten restrictions, to simplify procedures, and in general to save time and effort in the interests of more economical operation.

DETERMINATION OF SPECIMENS

The Division of Domestic Plant Quarantines in its quarantine administration, its transit inspection activities, and its survey features is not well equipped to determine all hosts and plant pathogens encountered in its activities. Outside the foreign plant quarantine service, elsewhere discussed, the need for pathological identification facilities may arise in connection with (1) specific quarantines (white-pine blister rust, and black stem rust), (2) plant disease specimens obtained by the transit inspection service, (3) host and pathogen materials collected in various survey activities, (4) specimens needing technical determination in the course of enforcement of the District of Columbia regulations, and (5) various host and pathogen materials coming to light in cooperative relations with the States (phony peach, peach mosaic, golden nematode, and potato rot nematode).

In general the need for technical help in identification is not very great in such problems as stem rust and white-pine blister rust where the host range is well established and the disease organism is easily recognized. Even here, however, outside help has been called in in such matters as the confusing pinon rust, the sorting out of ribes host species, and testing of barberry varieties to stem rust. In the identification of golden nematode survey collections and those of the potato rot nematode the Bureau has been altogether dependent on the Division of Nematology of the Bureau of Plant Industry, Soils, and Agricultural Engineering. Similarly, all specimens of abnormal citrus leaves encountered during the citrus canker survey have been submitted for bacteriological determination by the Bureau of Plant Industry, Soils, and Agricultural Engineering. Although the Bureau has now developed its own facilities and techniques for determination of the Dutch elm disease fungus, much help had to be obtained in the early days of this problem in sorting out this organism from others found in elm twigs.

Cooperation of this sort has been common all through the course of quarantine development. It began in the days of powdery scab and was prominent in the flag smut and take-all situations. In Woodgate rust and the bulb nematode quarantine, heavy reliance for accurate identification of specimens was placed on certain technical agencies in the Bureau of Plant Industry, Soils, and Agricultural Engineering and elsewhere. Uncertain or doubtful cases of peach mosaic in new areas are submitted as budwood for verification tests to the virus study centers of the same agency.

In this and other cases where an official determination is desired for legal reasons, it is standard practice to have critical disease specimens pronounced upon or confirmed by competent and recognized authorities outside the quarantine administration. In the same way disease specimens collected in the course of transit inspection, or in special survey programs, or in the extensive cooperative relations with the States cannot always be determined with finality within the quarantine administration, and must be referred for accurate disease diagnosis or pathogen identity to some recognized pathological or mycological expert.

It is gratifying to note that cooperation in these matters of determination has always been freely and generously contributed.

TEACHING

In general, plant pathology as taught in our colleges and universities normally includes a study of the nature and systematic relationships of disease organisms; their relations to their hosts in the matter of host range, crop damage, means of dispersal, seasonal adaptations, symptoms and their significance; and the various control or suppressive measures that may be employed to protect agriculture against these destructive intruders.

As explained above the quarantine and regulatory activities of State and national administrations constitute one element in the defense scheme of society against pest encroachment, and as such it merits a definite place in the stock of information and viewpoint presented for the instruction of a future generation of citizens. That this aspect of the pest control struggle has not yet become a routine item in all classroom instruction in plant pathology is due in part to the newness of its introduction on the scene, and perhaps in still greater degree to the absence of any comprehensive text book on the subject. The future will doubtless see this situation corrected so that an explanation of the part played by quarantines will be included as a normal feature in all courses of plant pathology.

Instruction on this phase of the subject on the college level should be an essential feature of a curriculum. The rapid recent developments in the quarantine field, the extent of operations now carried out in it, and the wide effects quarantine and regulatory measures may bring about in the lives and fortunes of innumerable citizens, all indicate the need for authentic college instruction and guidance to meet practical real life situations. Such teaching serves not only to disseminate helpful information to the vast body of the educated public, but it assures that the students of today who will be the agricultural leaders of tomorrow will be intelligently equipped to meet the problems that must inevitably arise for them in this field.

College teaching has another angle of interest to the regulatory field. Quarantine officials and inspectors, State and Federal, require a somewhat special training for their work, covering a group of subjects more or less overlapping into several of the normally accepted training courses. The teaching profession has an obligation to prepare students adequately for this type of service, perhaps, just as it attempts to provide training for other special branches of agriculture. At the present time several institutions have recognized this need and are endeavoring in various ways to fit some of their students for positions in regulatory work. Along with entomology, plant pathology would constitute a major subject in this scheme.

Below college level, high school and to some extent public school, curricula will probably come gradually to include something in skeleton form on the aims and methods of quarantine and regulatory projects, either by way of explanation of current local problems, or as a part of the general fund of knowledge indispensable to every citizen.

THE EXTENSION SERVICE

The Extension Service is an exceedingly important organization for quarantine and regulatory success. It is in fact a two-way channel--on the one hand collecting facts and figures useful and at times invaluable to the regulatory service, and on the other serving as effective dispenser of information, stimulator of community enterprise, and the molder of correct public sentiment. The County Agent or extension representative can do more to make or break a regulatory project locally than almost any other individual.

In line with the conception that a quarantine undertaking must have wide public approval and support to be permanently successful, State and Federal administrations alike are coming more and more to recognize the helpful role of the Extension Service in spreading dependable knowledge on local quarantine affairs, correcting erroneous impressions and encouraging a spirit of healthy cooperation among growers, business interests, and the public generally.

PLANNING

If we look upon a quarantine project, not as a mere bureaucratic function, but as a community undertaking, it is apparent that it should have the approval and support of a wide sector of at least the responsible and influential public. Without this general backing the chances for success are small. Because of this dependence on public support, it is an accepted policy in planning any important quarantine enterprise to consult with various critically placed groups or with their leadership so as to assure for the project beforehand a favorable public support. In other words, planning as well as carrying out must take into account the interested public.

Certain distinctions are needed here, however. While the general public can grasp readily and shrewdly matters of crop damage, project cost and economic benefit, and can decide wisely on the worth of a proposed program from this familiar viewpoint, it cannot be expected to understand the often complex relations in the biological field on which quarantine action must be based. Fortunately complete and detailed understanding in this difficult phase of planning is not necessary. The public places a vast faith in the integrity of the nation's scientific workers and is well content to trust their expert judgment in these intricate matters. Fortunately again, there are a number of sources independent of either State or Federal quarantine administration which can be called on to contribute to the planning process the special knowledge, wide experience, and sound viewpoint gained in personal studies and investigations in the technical phases of pest control. The help thus available in the formulation of quarantine plans from these specially trained and equipped scientists constitutes an invaluable element in setting up action programs.

Plant pathologists, either individually or through their organizations, are in a position to contribute materially toward the proper use and development of the quarantine method by their counsel and guidance. Whether this participation represents an official job responsibility, or arises out of personal interest in a technical subject affected by some quarantine, or concerns only group discussions leading to sound conclusions and opinions, or whatever the approach, it is surely the duty of the plant pathologist in his role of public service to help adjust this additional means of pest control correctly and effectively into the national scheme.

The history of past quarantine projects in the plant disease field brings out clearly the numerous and constructive contributions made by pathologists from the beginning in the planning process. Their intimate knowledge and special experience have helped to mold and direct quarantine action all along the way. Their opinions and viewpoints have been important factors in imposing, modifying, or revoking many quarantine and regulatory measures, and their criticisms and suggestions have tended to keep quarantine regulations, methods, and procedures on a more effective and practical basis. The helpful interest of many keen and well-informed pathologists outside the quarantine administration has profoundly influenced the course of such projects as powdery scab, Woodgate rust, white-pine blister rust, chestnut blight, and the Dutch elm disease. That same interest is currently active in such problems as the citrus canker survey, black stem rust, the golden nematode problem, and the peach virus diseases. Similarly, pathologists have effectively exercised a helpful role in the field of disease survey methods, the improvement of inspection methods, the development of new and more effective treatments, and in the discovery of new facts and relations. All such contributions aid materially, directly or indirectly, in the formulation of quarantine plans; they may promote greater effectiveness, lead to a more practical program, or reduce costs.

In addition to this general assistance given by pathologists to the planning of quarantine efforts, mention should be made of the valuable contribution to quarantine planning made by the National Plant Board and its subsidiary bodies, the four regional plant boards. These organizations are made up of representatives from the quarantine and regulatory services of all States, but function on a purely advisory basis. Because of their familiarity with State quarantine problems, these groups are peculiarly fitted to understand and assess the worth of all quarantine proposals, State or Federal. They thus constitute a competent board of experts and their viewpoints and opinions carry tremendous weight in quarantine planning. It is noted, however, that a large majority of board members are primarily entomologists, and for this reason plant board interest is substantially greater in insect matters than in plant disease problems.

To some extent this unbalance is compensated for by an arrangement made in 1944 with the American Phytopathological Society, whereby a permanent committee appointed by that organization has been assigned to confer on disease problems arising in the quarantine field with the Bureau of Entomology and Plant Quarantine, and after studying these to report to the Bureau its analysis and recommendations. It may be expected that this committee will not only benefit the quarantine administration by its deep technical insight into the pathological aspects of the situations reviewed, but will also serve as a channel to bring back to the Society a clearer understanding of quarantine aims and viewpoints.

Outside the plant quarantine administration but still within the Department of Agriculture itself are to be found a number of pathologists who can be called upon to help in the quarantine planning process, particularly by presenting and evaluating all the known facts and relations available to each of these specialists in his own special field of study. The administration relies heavily on this source of help, and regards these contributions as of special official weight.

THE TRANSIT INSPECTION SYSTEM

Transit inspection was begun in 1920 (46) to assist in the enforcement of the white-pine blister rust quarantine which prohibited the movement of white pine and ribes nursery stock from the infected eastern areas across the plains into the then still rust-free regions of the Pacific area. Arrangements were made at that time to place inspectors at strategic midwest traffic centers and transfer points so that freight, express, and parcel post shipments could be checked on their way to the West. This type of inspection was found so effective that the service was set up as a specific project on July 1, 1930, and expanded to provide the same type of assistance in enforcement of other Federal domestic quarantines and to furnish reports to State inspection officials of shipments observed to be moving in these channels in apparent violation of State plant quarantines or nursery inspection requirements. Assistance is also given to the foreign plant quarantine service by calling attention to foreign shipments of plants and plant products found to be moving in violation of foreign plant quarantine regulations. It is to be understood that transit inspectors are empowered to take appropriate protective action in the case of infractions of Federal domestic quarantines, but merely report upon infringements of State quarantines or of violations in the foreign plant quarantine field.

Transit inspection is now operating, either throughout the year or seasonally at 16 major freight, express, and parcel post distribution and transfer centers, and keeps under scrutiny traffic movements in all directions through such bottlenecks as an aid in the enforcement of the eight Federal domestic plant quarantines. Of these, the quarantines on account of white-pine blister rust and black stem rust are of particular interest to plant pathologists.

It should be added that several States assign inspectors to cooperate in transit inspection on a full or part-time basis.

At first glance it might seem impossible for a limited number of inspectors to cover effectively the tremendous mass of commodities pouring through the traffic channels of our vast network of public carriers. Yet from much study, planning, and experience in the development and application of methods of selective examination, helpful cooperative relations with common carriers, and arrangements with postal officials, an unexpectedly large coverage has been attained of shipments of quarantine interest in the moving streams of plants and plant products. Further, through the reporting and investigation of apparent violations and the distribution of helpful information on procedures, the transit inspection service is able to keep the public on a far higher plane of compliance with regulations than could be obtained at equal cost in any other way.

FEDERAL DOMESTIC PLANT QUARANTINES

Domestic plant quarantines represent Federal efforts to prevent the interstate spread of injurious pests by the exercise of control over interstate commerce. The States relinquished this control to the Federal government and it was made operative by the Plant Quarantine Act of August 20, 1912. Section 8 of this Act gives the Secretary of Agriculture power to place a State or group of States under quarantine on account of a specified injurious agricultural pest; to prohibit or regulate the interstate movement therefrom of plants, plant products, and other materials likely to disseminate the pest; and to make such prohibitions or regulations applicable to the whole State or to a specified portion thereof. It is important to note that this grant of power may be exercised only over such articles or materials while they are moving from one State to another in interstate commerce. Control over movements wholly within the State itself (intrastate movement) comes under the State's own powers.

Because the Federal power is thus definitely limited, many pest situations involving complex quarantine action require a combination of both State and Federal quarantines to obtain effective results. In addition to this possibility of concerted quarantine action by both State and Federal agencies, a further provision of Section 8 of the Plant Quarantine Act authorizes the Federal authority to cooperate with the State in the enforcement of State quarantines. Liberally construed, this cooperative provision permits Federal assistance to be given in many ways to State-planned quarantine projects, whether a Federal quarantine is in effect on the subject, or whether only a State quarantine has been promulgated.

During the period from the passage of the Plant Quarantine Act (August 20, 1912) to the end of 1949 there have been promulgated ten Federal domestic interstate quarantines on plant disease subjects. For reasons of administrative expediency two of these (No. 15, on sugarcane from Hawaii and Puerto Rico, and No. 60, on sand, soil, or earth from Hawaii and Puerto Rico) are administered by Foreign Plant Quarantine personnel and are, therefore, included in that Division's list. Six of the remaining eight have been revoked, thus leaving in effect at the present time only two of these measures--black stem rust, No. 38; and white-pine blister rust, No. 63.

Miscellaneous Disease Problems

In addition to these eight specific problems a great many other disease situations have from time to time come up for quarantine consideration, but for various reasons have been set aside as not requiring Federal quarantine action. An incomplete but typical list of these would include the following:

Quick decline of citrus (virus)
 Internal cork of sweetpotatoes (virus)
 Several prunus virus diseases such as the "X" disease, peach yellows, peach rosette, cherry buckskin, cherry dwarf, peach wart, etc.
 Rose mosaic (Marmor rosae)
 Sugarcane mosaic (Marmor sacchari)
 Phloem necrosis of elm (virus)
 Narcissus mosaic (virus)
 Walnut brooming disease (virus)
 Potato rot nematode (Ditylenchus destructor)
 Root knot nematode (Heterodera marioni) (= Meloidogyne spp.)
 Potato bacterial ring rot (Phytomonas sepedonica) (= Corynebacterium sepedonicum)
 Poplar canker (Dothichiza populea)
 Willow scab (Physalospora miyabeana)
 Oak wilt (Chalara quercina)
 Mimosa wilt (Fusarium oxysporum f. perniciosum)
 Filbert blight (Cryptosporella anomala)
 Azalea flower blight (Ovulinia azaleae)
 Camellia flower blight (Sclerotinia camelliae)
 Ozonium root rot (Ozonium (Phymatotrichum) omnivorum)

Federal quarantine power has not been invoked for these and numerous other similar plant disease situations for any one of a variety of reasons or combinations of these.

1. The disease may be too unimportant nationally to justify expensive quarantine effort or trade disturbance; costs would be out of proportion to the benefits to be expected.
2. Quarantine usefulness is questionable because of a still unknown pest distribution, or lack of knowledge on key features, or the recognized inadequacy of available measures in preventing spread, or the existence of important uncontrollable means of spread.
3. Reasonably successful means of control are available, which may largely obviate the need of Federal quarantine measures.
4. Certain problems can be solved more effectively by State than by Federal quarantine action.
5. The Federal agency by virtue of well-planned cooperation with the States in their quarantines or other regulatory measures can often fulfill its responsibilities without imposing an official Federal quarantine.
6. The level of national support may be inadequate as indicated by popular apathy, adverse influential sentiment, undeveloped technical opinion, the clash of conflicting interests, or in the matter of minimum necessary appropriations.

The eight plant-disease problems which at one time or another have engaged Federal attention so deeply as to have resulted in domestic quarantine promulgation are here reviewed to bring out their chief relations to the field of plant pathology.

The Bulb Nematode

The bulb and stem nematode Ditylenchus dipsaci has long been known on numerous hosts other than bulbs. Its frequent occurrence to a damaging extent in clover and alfalfa fields in the

Pacific States was the basis for a quarantine hearing on October 2, 1923,² but the evidence there brought out indicated that this nematode was already widely distributed on these hosts. The injuries to alfalfa and clover in the Western States were dependent, it was thought, on locally favorable climatic conditions, and the quarantine proposal was dropped.

In 1926 increasing reports of bulb nematode infestation in domestic narcissus bulbs led to its inclusion in the narcissus bulb Quarantine No. 62, effective July 15, 1926,³ as a reason for promulgating this measure along with the greater bulb fly (*Merodon equestris* Fab.) and the lesser bulb fly (*Eumerus strigatus* Fallen). This quarantine aimed to establish Federal regulatory control over all interstate movements of narcissus, with the object of reducing or suppressing these three bulb pests in the country's bulb-producing areas. The plan provided for a field and a harvest inspection, treatment by fumigation or hot water methods for infested lots, and certification for interstate movement. Additional regulatory procedures to be carried out by State authority governed the culture and production of narcissus.

A report on the inspection and certification operations of this quarantine for a single typical year, 1929, in 29 States and the District of Columbia listed almost 175 million bulbs of Polyanthus type examined and nearly 100 million of the Daffodil type, and over 160 million bulbs of both types were certified, and over 50 million daffodil bulbs had to be treated.⁴

Quarantine No. 62 together with its regulations was revoked, effective April 1, 1935⁵; the lesser bulb fly had already been dropped from the quarantine June 20, 1932. The reasons given for revocation were that both bulb nematode and greater bulb fly incidence had steadily increased so that the expected general suppression had not been realized. Contributing to this disappointing result was the fact that both pests were becoming more widely spread; that the bulb eelworm was now known from over 50 hosts, many of them native plants; and that the nematode was present in and presumably being carried about by other bulbs not covered by the quarantine. The effectiveness of the hot-water treatment against the bulb nematode had likewise been called into question. Under these circumstances it seemed best to withdraw the Federal quarantine and leave both cultural control as well as the certification for interstate shipment in the hands of the individual States, with such assistance by the Federal agencies as could be furnished in special problems. This arrangement is still in effect.

Considering only the nematode aspect of this quarantine as of primary interest to the plant pathologist, it is clear that neither distribution nor host relations were sufficiently well known at the outset. We may perhaps interpret much of the later reported increase in distribution as representing merely late discoveries rather than actual spread. Again, the complex host relations that later came to light provided another example of the unfortunate necessity of making quarantine decisions before adequate information was available. Finally, the doubt cast later on the efficacy of the hot-water treatment traces back to technical sources rather than to faulty quarantine judgment.

It is easy to attribute the lack of success and the final abandonment of this quarantine effort to imperfect official planning. It should be recognized, however, that the control scheme attempted was a legitimate conception hopefully designed to serve the national interest. Its weakness lay in the lack at the outset of adequate knowledge of host range, distribution, and control methods. Thus, lag in the technical field was an important element in the unsatisfactory outcome of this effort. This viewpoint attaches no blame to the technical agencies concerned; for various reasons they were unable to contribute immediately all the data needed for sure quarantine judgment. The situation merely emphasizes that intimate interrelation must prevail between the quarantine function and other phases of plant pathology, and that close teamwork is important in providing a sound basis for quarantine action.

Black Stem Rust

The black stem rust of cereals (*Puccinia graminis*) as a pathogenic species is generally present in the United States and has been here since early colonial days; further, it is readily spread by wind. Because of these relations, quarantine would seem to be useless, and only control measures could be considered.

Yet quarantine action has a definite place in the stem rust situation, because of the important role of the alternate hosts (*Berberis*, *Mahonia*, and *Mahoberberis*) in starting early local infec-

²S. R. A. (U. S. Bur. Entom. & Plant Quar. Service & Regulatory Announcement) 1923, p. 118.

³S. R. A. 1926, p. 70.

⁴S. R. A. 1930, p. 48.

⁵S. R. A. 1935, p. 10.

tions and in serving as a breeding ground for new and more virulent stem rust races. Because of these highly dangerous characteristics, rust-susceptible members of the barberry group have been sentenced to extermination in the important grain-producing areas of the country. It is only in this special feature of barberry eradication that the quarantine powers of both Nation and State have been called upon.

Quarantine effort aims to prevent the movement of rust-susceptible barberry and mahonia into grain-growing areas, and to prevent replanting of these undesirable rust hosts in areas already cleared from them.

The campaign to eliminate these dangerous hosts from the scene involves: 1 -- the destruction of rust-susceptible barberry and mahonia plants throughout the areas producing wheat and other cereals attacked by stem rust; 2 -- maintaining these areas free from these alternate hosts on a permanent basis; 3 -- restriction of all barberry and mahonia planting throughout the protected areas to species and varieties determined to be rust-resistant; 4 -- the testing of these varieties to establish their rust resistance or susceptibility; 5 -- supervision of nurseries growing barberry and mahonia plants for sale and distribution and the certification of their rust-resistant species and varieties for movement; 6 -- prohibition of movement into the eradication States of barberry seeds, which because of ready hybridization are likely to produce rust-susceptible plants; and 7 -- transit inspection at key points and traffic bottlenecks to assure that the restrictions and requirements on seeds and plants of barberry, mahonia, and mahoberberis are being observed.

Federal Domestic Plant Quarantine No. 38 was issued, effective May 1, 1919⁶. It prohibited shipment into certain States where barberry removal was in progress of plants of 31 named species of barberry and three of mahonia. A widespread voluntary cooperation of nurserymen was arranged to assure against distribution of the susceptible plants.

The quarantine was revised several times to take care of problems as they arose. Mahonia repens was removed from the list of susceptible plants; unrooted mahonia cuttings were allowed to move without restriction for decorative purposes, and additional States were included in the protected list.

The most recent revision of May 1, 1949, designated through administrative instructions 39 species and varieties of barberry, mahonia, and mahoberberis, regarded as rust-resistant and thus eligible for interstate movement under permit; the regulatory control over host movement was extended to all areas of the continental United States; and a prohibition was placed on the movement of fruits and seeds into the eradication States unless these could be shown to have come from resistant plants in which case movement under permit was allowed.

As above indicated, quarantine activity constitutes but a subsidiary element in the black stem rust control program, the chief feature of which has been the elimination of the susceptible alternate hosts from extensive grain-growing areas. The technical knowledge and experience basic to this ambitious undertaking takes its rise far back in European history. According to Fulling (15) observations in Rouen, France, and elsewhere in Europe in the 17th century linked wheat "blast" to the barberry; early in the 19th century barberry suppression was being carried out in Germany by legal orders; France, Denmark, and Austria, likewise, enacted such laws; Connecticut, Massachusetts, and Rhode Island attempted barberry eradication to protect wheat in the 19th century also; North Dakota in 1917, and Iowa, Montana, Nebraska, Minnesota, Michigan, South Dakota, and Wisconsin recognized the role of barberry in perpetuating rust in 1919 and banned these shrubs by law; Wyoming came into the list in 1921 and Oregon in 1923.

State efforts to suppress susceptible barberries were more or less unified by the eradication effort established in 1918 by the U. S. Department of Agriculture which attempted to inaugurate a common program in 13 wheat-growing States--Colorado, Illinois, Indiana, Iowa, Michigan, Minnesota, Montana, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin, and Wyoming. Later, other States joined in the control program. A similar movement was begun in 1917 in Canada which later included the provinces of Ontario, Manitoba, and Saskatchewan. It was to strengthen this extensive protective campaign that Federal legal powers were brought into the scene in 1919 in the form of Quarantine No. 38.

Pathological contributions to this stem rust problem have been numerous and varied. Only those of key significance in the quarantine phases of the problem can be referred to here. Outstanding of course is the proof by De Bary in 1865 (14) of the specific unity of the aecial barberry stage of the rust with that on wheat. This brilliant work vindicated the conclusions long before reached by observant growers, and placed control measures on a sound technical basis.

⁶ S.R.A. 1919, p. 58.

Two other contributions have been fundamentally important in the quarantine sense. One of these demonstrated the sexual process taking place during the barberry stage and gave convincing assurance that different rust strains may thus meet, cross, and produce new races on the barberry (11). The other embraces the results of long-continued and careful studies by many pathologists on the characters, areal range, and host relations of over 200 distinct races of wheat rust (51, 52). These race studies in stem rust have been so extensive and of such far-reaching significance that they may be said to have established a new viewpoint in quarantine philosophy--the necessity of taking into account these individual and varying strains as pathogenic units instead of regarding the species as the sole and final unity.

That the quarantine measures depended on to strengthen the general stem rust control campaign have well served their purpose of preventing the continued planting of susceptible alternate host species and varieties in the protected States may be attributed to several factors. In the first place the needed quarantine steps were of simple and obvious type; second, restrictive action both at the outset and in its subsequent developments has been soundly grounded on well-established biological relations; third, the quarantine procedures adopted have had the general approval and support of plant pathologists everywhere; fourth, the nursery industry has from the beginning cooperated most effectively in complying with the planned procedure. Finally, the national importance of the wheat crop, its tremendous value, and its wide culture have all served to create strong public support for the stem rust campaign including its accessory quarantine feature.

Chestnut Blight

The chestnut blight or canker fungus (*Endothia parasitica*) was probably brought from Asia in chestnut nursery plant importations some years prior to its recognition as a definite chestnut parasite by Murrill in 1906 (41). In contrast with the situations in potato wart, white-pine blister rust, and the Dutch elm disease where foreign behavior gave advance notice of destructive possibilities, the chestnut blight fungus was unknown as a serious pathogen until it came into contact with the very susceptible American chestnut (*Castanea dentata*). At the time of its discovery it probably had been spread generally by nursery stock distribution and spore dispersal. By 1908, it was reported to be widely distributed in the Hudson River Valley and in the vicinity of New York City.⁷

In the years prior to the Plant Quarantine Act of 1912, control or suppressive measures were possible only through State legal powers supplemented by Federal technical assistance. Typical of such efforts was the work of the Pennsylvania Chestnut Blight Commission instituted early in 1912 (45) to bring all available State resources to bear on the blight problem. These early efforts were somewhat confused by the occurrence of other similar fungi on the chestnut and by failure in some quarters to recognize promptly the seriously parasitic character of the new intruder (10). The discovery of the fungus in Asia in 1913 helped to clear up these early difficulties (18, 48).

A Federal domestic quarantine was brought up for consideration at a hearing on May 18, 1915.⁸ At that time the blight was known to be present all through New England, New York, the middle Atlantic States of New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and West Virginia, and cases had been reported from North Carolina, Ohio, Iowa, and Nebraska. The impossibility of preventing further natural spread in the East by quarantine measures was now recognized, and it was indicated that State quarantines to prevent diseased nursery stock distribution were preferable to Federal action. This attitude has continued until the present; several Western State quarantines of protective type are still in effect.

At the beginning of the blight campaign there was intense activity in every line that held hope of suppression, control, or delay in spread. Spraying methods, chemical treatments, pruning operations, and isolation procedures all failed to bring appreciable results (38). Although it was soon apparent that the gradual onward march of blight could not be prevented, a system of patrol to suppress foci of infestation far in advance of the main body was instituted, and this step appears to have rendered valuable service in appreciably delaying blight progress and thus giving an opportunity for the orderly salvage of large quantities of stricken chestnuts for timber or lumber use.

From the outset emphasis has been placed on a search for blight-resistant chestnuts (18). Search was made in our native chestnut stands for individual trees or healthy tiller shoots which

⁷S. R. A. 1915, p. 25.

⁸S. R. A. 1915, p. 25.

had survived the general destruction, and might thus possess resistant characters rather than merely represent accidental escape. No outstanding results have been obtained from this search. Attempts have also been made to incorporate resistance in acceptable hybrids by crossing the American species with commercially useful resistant Asiatic chestnuts, a necessarily slow and tedious process. While this line of attack, persistently carried out by the Bureau of Plant Industry, Soils, and Agricultural Engineering, has produced promising results, there is as yet no blight-resistant cross that can match the native species in all the desirable features of timber character, nut quality, seed reproduction habit, and tillering ability. A third line of effort is underway to search out the best types of Asiatic chestnut having inherent resistance to blight, and to distribute seeds of these for planting in forests as a substitute for the vanishing native species (19). Considerable progress is being made in this direction, and this movement is likely to gather impetus with the years.

As was predicted, all efforts to stop or materially delay the progress of chestnut blight have failed, and the fungus has swept southward and westward practically unchecked through the eastern chestnut stands. It has now reached almost to the southern limits of the chestnut in the Appalachians, and has been found as well in isolated spots in the far West and British Columbia.

From the quarantine point of view the lack of success in preventing spread in the eastern chestnut range can be attributed neither to early misunderstandings on the relations and potentialities of the blight fungus (9), nor to inability to marshal sufficient funds and manpower to fight the intruder. Quarantine effort is most effectual in connection with the controllable movement of pest-carrying materials, and here found itself relatively helpless against natural wind transport or bird and animal dispersal of the tremendous spore population produced by an aggressive parasite on an extremely susceptible and plentiful host. Undoubtedly, the State restrictions imposed on nursery stock movement were of considerable value, since their delaying action gave time for an orderly utilization of tremendous quantities of the dead and dying wood and timber products. In spite of this slowing down, however, the pest swept inexorably on its destructive way. Even the drastic measure of complete host suppression in the originally infected area, so as to eliminate this inoculum at the source, could scarcely have been expected to succeed, partly because of the extensive distribution of blight when its true nature was first recognized, but still more because of the host's unusual capacity for tillering. The fungus could perpetuate itself on the succession of shoots for many years.

In this eastern campaign the chestnut blight fungus is likely to remain for long a classic example of extremes in the quarantine sense--mild behavior in its native home, unusual virulence on its new American host, uncontrollable natural dispersion by wind, failure of conventional control methods, and only partial success as yet in the one hopeful feature of developing resistant chestnut types.

In the Pacific region where the chestnut is not indigenous the struggle against blight has been more successful. Scattered plantings of American, European, and Asiatic chestnuts have been made in the three coast States and in British Columbia, Canada, and blight centers have been located in all of them (20). However, eradication measures have been successful in Washington and Oregon, and the repressive measures taken in the few infected California plantings seem to be preventing further spread (1).

Citrus Canker

A review of the long and remarkably successful campaign against citrus canker (*Bacterium citri* (Hasse) Doidge) (= *Xanthomonas citri* (Hasse) Dowson) will appear in a forthcoming Supplement of the Plant Disease Reporter. This story covers developments from the finding of the organism in 1913 to the recent and entirely negative survey operations carried out in Texas and Louisiana, 1947-49. Activities through this period in the seven Southern States concerned included intensive and repeated survey, on-the-spot destruction by fire of all infected trees, the meticulous supervision of citrus nurseries and their environs, and the eradication of countless wild, escaped, and abandoned citrus trees (17). This energetic and sustained eradication effort was begun by the southeastern citrus States as soon as the destructive character of the disease was recognized (3). The program set up in these States was strengthened and supported by the Federal government through the Bureau of Plant Industry from 1915 onward to 1935 and continued thereafter by the Bureau of Entomology and Plant Quarantine.

The complete elimination of a bacterial disease of virulent and contagious character from widely scattered centers in seven States would seem to be an almost hopeless undertaking. That its suppression was accomplished not only effectively but rapidly throughout this wide area was

not only due to the deep and sustained interest of the Federal agencies, but still more to prompt and energetic measures taken by the States themselves, and also to the outstanding assistance and support accorded by citrus growers, nursery firms, and the public generally. Few programs of regulatory nature have commanded such complete cooperation among the various elements concerned as this canker problem. It was truly a community undertaking.

Largely because of the prompt and determined action taken at the outset encouraging results were soon obtained (34). Florida had largely suppressed its numerous canker spots by 1916; the State continued its drastic measures for its few recurrent cases until 1927, since which date no canker has been known there. South Carolina saw the end of its canker in 1916, and Georgia in 1917; in Mississippi the last traces were noted in 1922; and Alabama has been canker-free since 1927. The disease held out for some years in Louisiana where nurseries and commercial citrus plantings were pronounced free from canker in 1940; and in Texas where no canker has been seen in the nurseries or commercial orchard citrus since 1941. The last known Texas record of citrus canker was a single leaf of a small escaped seedling found in 1943.

The cooperative Federal-State search for canker continued in Texas until 1944 and then after two inactive years was resumed in 1947 to 1949 in Texas and in Louisiana in 1949. At the end of 1949 no case of canker has turned up in either State, and the evidence from these extensive and thorough survey efforts seems to justify a confident hope that this virulent citrus pest has been completely exterminated from the whole United States mainland.

Foreign Quarantine No. 19, effective January 1, 1915,⁹ has been maintained since to exclude rigidly all foreign propagating materials likely to carry the canker organism, and this was supplemented by Foreign Quarantine No. 28, effective August 1, 1917, excluding citrus fruits susceptible to canker infection.¹⁰ No Federal domestic quarantine to prevent interstate spread of canker has been imposed. Reliance was placed on the quarantine and regulatory measures set up by the several affected States, which, though largely intended for suppression purposes within the States themselves, were deemed adequate to deal also with problems of interstate spread, especially when supplemented by exclusion action taken by the relatively few citrus-producing States. These quarantine arrangements have appeared to work well; there has been no record of interstate spread of citrus canker in nursery stock channels through the years of quarantine operations.

At the outset Federal activities in the eradication of citrus canker were centered in the Bureau of Plant Industry, and this leadership was continued until 1935 when, in accordance with a general reallocation of Department functions, this project, along with several other disease control features, was taken over by the Bureau of Entomology and Plant Quarantine. Since that date it has been a responsibility of the Division of Domestic Plant Quarantines to bring to its present apparently successful state the eradication operations so energetically initiated and so largely accomplished in the early years by State and Federal cooperation.

For such an outstanding disease the relations to plant pathology have been comparatively simple. The establishment of the bacterial nature of citrus canker and the isolation and classification of the organism involved (24) provided a sound basis for control procedures. Methods of spread and the extremely contagious character of the malady (4, 57) were early known from field observations or were readily deducible from these. Questions of longevity in leaves and in soil (16) had to be answered, however, as well as the relation of the organism to fruit and containers (33). The destruction of infected trees in situ by fire was a grower contribution, adopted after ordinary spraying, pruning, and other similar practices had failed to check the spread. Throughout the whole campaign, however, it has been necessary to have doubtful or critical specimens identified or confirmed by expert bacteriological procedures, since field observation cannot be confidently relied on for canker determination. This service has been effectively rendered over the years by the Bureau of Plant Industry, Soils, and Agricultural Engineering.

The Dutch Elm Disease

The Dutch elm disease (*Ceratostomella ulmi* (Schwarz) Buisman) was first found in the United States in 1930 at Cleveland and Cincinnati, Ohio. Three years later it was found to be well established in parts of Connecticut, New Jersey, and New York around the Port of New York. In 1933 and 1934, diseased trees were found at Baltimore, Maryland; Norfolk, Virginia; and Indianapolis, Indiana. Concurrently, elm burl logs from Europe carrying *C. ulmi* and bark beetle vectors of the disease, were found entering the ports of New York, Baltimore, and Norfolk. A search of import records revealed that since 1926 about 500 elm burl logs had entered at these

⁹S.R.A. 1914, p. 89. ¹⁰S.R.A. 1917, p. 104.

ports and at New Orleans, Louisiana. They had been shipped through and into 21 eastern, southern, and midwestern States over 13,000 miles of railroad. Subsequently, disease centers were found at Brunswick and Cumberland, Maryland; Athens and Ravenna, Ohio; Binghamton, New York; Wilkes-Barre, Pennsylvania; and Old Lyme, Connecticut. All but the last two locations are along railroads known to have hauled imported elm burl logs. In 1948, Dutch elm diseased trees were found in Denver, Colorado, but no clue as to how the disease reached there has developed.

All elm species occurring naturally in the United States are susceptible to the Dutch elm disease. They occur somewhat continuously east of the Great Plains and are planted extensively in all parts of the country. Asiatic elms are somewhat resistant to the disease. A few selected American elms and hybrids have shown disease resistance. A selected strain (Christine Buisman) of a European elm is highly resistant. There is no established method of making an elm immune from infection or of curing a diseased elm.

The Dutch elm disease is spread chiefly by two species of bark beetles. *Hylurgopinus rufipes* is a native insect and probably occurs throughout the natural range of elms. *Scolytus multistriatus* became established in the Boston and New York areas apparently soon after 1900, and subsequently in the Hudson, Susquehanna, Potomac, Ohio, and Mississippi River Valleys, and at Rochester, New York, and Denver, Colorado. The disease may be kept in check by destroying bark beetle sources and by spraying healthy elms with DDT to prevent their inoculation by these fungus-carrying insects.

During the 1930's an attempt was made to control and eradicate the Dutch elm disease in the United States by finding and destroying diseased elms and bark beetle sources in the known infected areas. Foreign Quarantine No. 70, effective October 21, 1933,¹¹ placed an embargo against imported elm materials which may carry the Dutch elm disease fungus and bark beetle carriers. Domestic Quarantine No. 71 was established, effective February 25, 1935,¹² to prevent the movement of hazardous materials from infected areas in Connecticut, New Jersey, New York, and Pennsylvania. The quarantine did not prevent persistent local spread of the disease by bark beetles, but the control effort probably reduced the rate of spread materially. When large scale control work was terminated in the early 1940's, the domestic quarantine was revoked, effective May 1, 1947.¹³

Various factors were concerned in the revocation of Domestic Quarantine No. 71. Both experience and expanding knowledge indicated that control was essentially a local problem and was thus predominantly a State responsibility. While interstate movement of nursery stock could be controlled by regulatory action, this was a relatively minor element in spread, and such movement could be restrained quite well by established State nursery stock inspection methods. Quarantine methods could not hope to prevent natural dispersal of the insect carriers, and were largely ineffective in controlling local, erratic movements of elm wood products in which both the fungus and carrier could possibly be disseminated. There were survey difficulties. Survey costs were high, and although identification in suspected trees could be made with sureness; evidence indicated that both fungus-infected wood and spore-bearing insect carriers were likely to exist in the areas outside of known infestations where tree symptoms had not developed. These relations not only brought uncertainty into the basic quarantine survey problem but debarred a confident prediction for final success of the program. This uncertainty was increased when further survey showed the insect carriers to be distributed more widely than at first was suspected.

In the field of popular support this uncertain outlook was a discouraging element. The modest reputation of the native elm as a timber tree also kept enthusiasm lukewarm in many rural areas; and while shade elms in towns were highly valued, their enforced removal sometimes stirred resentment and frequently imposed heavy costs on property owners and municipal finances. On the whole, therefore, public interest and approval never did attain the strength and momentum necessary for the success of such a widespread and costly undertaking.

With the revocation of Quarantine No. 71 problems of control, as well as prevention of spread now center in individual States, and several western States have since then promulgated interstate quarantines to protect themselves against Dutch elm disease introduction from eastern sources. Federal interest in the problem is still maintained and the Bureau of Entomology and Plant Quarantine maintains a laboratory for making conclusive identifications of the Dutch elm disease organism, thus distinguishing it from other vascular pathogens causing somewhat similar symptoms. The Bureau and a few State agencies are engaged in testing bark beetle control

¹¹S.R.A. 1933, p. 245.

¹²S.R.A. 1935, p. 4.

¹³S.R.A. 167; 1947, p. 4.

measures which may be effective and practical for elm owners, city foresters, and arborists. Sanitation measures and spraying with DDT are receiving close attention. State and commercial pathologists are investigating therapeutic materials and techniques for controlling the Dutch elm disease. Federal and State pathologists are continuing efforts to find and make available resistant elms which will be suitable for home, park, and street planting.

Several American pathologists have contributed materially to what is known about the Dutch elm disease. For many years L. M. Fenner handled the large volume of identification work and developed special techniques for large volume culturing. W. Banfield, A. E. Dimond, and A. Feldman have contributed much on pathological processes, and, in addition, the last two have developed chemotherapy techniques. W. H. Rankin, M. A. McKenzie, H. V. Wester, and E. G. Rex have devoted much time to control programs and methods. Curtis May, D. S. Welch, Roger Swingle, and J. M. Walter have led in the development of resistant strains. O. N. Liming has been directly connected with all phases of the control program since its inception in 1930.

Flag Smut

Action was taken by Foreign Plant Quarantine No. 39, effective August 15, 1919, to shut out from certain specified countries seed or paddy rice, on account of two diseases--flag smut (*Urocystis tritici*) and takeall (*Ophiobolus graminis*)--as well as to regulate the entry of wheat, oats, barley, and rye from those specified countries. Concurrently with the hearing which preceded promulgation of this quarantine and on the same date, July 15, 1919, a similar hearing was held¹⁴ to discuss the need for a domestic quarantine on the same two diseases and on the wheat nematode (*Tylenchus (Anguina) tritici*). Flag smut had been found in Illinois where it was thought to have become established through a wheat shipment from Australia brought in as an emergency measure during World War I. The takeall disease was known to be present in Illinois and Indiana, and the wheat nematode was reported to occur in Virginia, West Virginia, and Georgia. It was proposed to consider quarantine restrictions on the interstate movement from these several States of wheat, oats, rye, spelt, and emmer.

However, the hearing developed much information and viewpoints which materially affected the proposed action. The eelworm disease, it was brought out, had been long present in the country, and though probably widely distributed outside the three States mentioned, had not shown any pronounced tendency to spread, and could be controlled with reasonable effort by the States concerned. It was forthwith dropped from the quarantine consideration.

In the case of takeall, the fact that the fungus concerned was unlikely to be carried to any extent on seed rendered quarantine control over seed or grain practically useless. Moreover, local control was also possible and there was grave doubt that the fungus was restricted to the two locations then known to be infected.

The flag smut outbreak was considered more threatening. The fungus was definitely known to be seed-borne and had a bad record in Australia and other wheat areas of the world. Yet the area affected in Illinois was small; considerable hasty survey had failed to uncover other infection centers; Illinois was taking effective steps to deal with the infected center; and available wheat varieties immune or highly resistant to this smut offered a promising means of control. Because of these considerations, it was concluded that reliance should be placed on the control features mentioned or on State quarantine action as needed, and that a Federal interstate quarantine should not be imposed for either flag smut or the takeall disease.

Later developments have largely justified that decision as far as this midwest flag smut center is concerned. It is true that other limited areas in Kansas and Missouri were later found to have flag smut infection. But the consistent use of resistant wheat varieties in these areas has reduced the flag smut incidence in all three States to a very low level, as indicated by a survey made in 1932 (40).

In August 1940 cases of flag smut were discovered in a limited area of the State of Washington. Observations here in 1941 and again in 1943 (25, 53) showed a slight spread to adjacent fields but no increase in intensity. No quarantine action followed this finding.

Although the flag smut situation has thus been dealt with in both the areas mentioned without resort to Federal quarantine action, this disease presents several features of quarantine interest, which at the same time lie in the field of plant pathology. 1-- As a basic food crop of the nation, wheat deserves the highest degree of protection from pest damage that can be secured; 2-- while resistant varieties were happily available in the midwest area, it is acknowledged that much of the wheat grown on the Pacific slope comes from varieties similar to the Australian types known

¹⁴S. R. A. 1919, p. 85.

to be susceptible to flag smut; the resistant variety situation for eastern wheat areas has not been adequately investigated; 3-- several physiologic races are known for flag smut (58); the evidence indicates that the midwest and Pacific coast centers involve separate smut strains (26); 4-- the seed-borne nature of flag smut merits attention, particularly in the matter of developing a dependable and practical seed treatment.

Whether or not quarantine methods may be needed for this disease in future will largely depend on the results of investigations by pathologists on these flag smut relations.

The Golden Nematode

The golden nematode of potato, *Heterodera rostochiensis* Wollenweber, is recorded as occurring on the potato in Germany in 1881; the potato was recognized as a host there in 1909, and this nematode was set apart as a definite species by Wollenweber in 1923, thus changing its previous status as a strain of the sugar-beet nematode, *H. schachtii* (43). Other European records indicate its presence in Scotland in 1913, in England and Ireland in 1917, in Sweden in 1922 and in Denmark in 1928 (12). It is also reported in Holland. In Europe it has been notably damaging to potato production (8).

The golden nematode was first found in North America in 1941, associated with low yields in a few Long Island, New York, potato fields. Intensive surveys there in subsequent years indicate that the soil in about 8,000 acres of potato lands around the original center is more or less infested by this potato root parasite. Considerable search (37) in other potato producing States has failed to disclose this nematode elsewhere.

It would appear that the golden nematode was brought to Long Island from Europe about 1930. Its channel of entry is unknown. Potatoes, the logical carrier, have been excluded by quarantine from practically all of Europe since 1912 and nursery stock from abroad is required to be free from soil. It may be significant, however, that during the last three years golden nematode cysts have been recovered and definitely identified from 14 lots of soil remnants remaining around plants arriving here from European sources. (56).

The golden nematode quarantine problem need take no account of natural means of spread except in a purely local way, and its host range, being practically restricted to the potato and the tomato, simplifies the quarantine effort. On the other hand, control of the human activities, which alone are concerned in distant dissemination, involves several troublesome features.

In review of the difficulties attending quarantine action in this case, survey limitations deserve first mention, since the actually infested areas must be established with certainty before quarantine regulations are applied. In the entire absence of reliable plant symptoms we are forced to base survey on the presence or absence of the barely visible cysts. Unfortunately neither direct search on potato roots for developing cysts, nor analysis of soil samples by washing-screening methods to recover these cysts, is entirely satisfactory for scanty or incipient infestations. Both methods work well when cysts are numerous, but inability to find scattered cysts in soil or scanty infestations on plant roots, except by chance, may mean overlooked infestation spots from which spread can occur before the cyst population rises to the detectable range.

Again, total eradication, while a drastic and costly measure, would be nationally profitable, perhaps, but the field soil treatment so far used has been only about 85 percent successful in nematode kill. It is assumed here that for such an indispensable food crop as the potato almost any expenditure which would successfully suppress the nematode or prevent spread of this persistently destructive pest to other potato areas would be amply justified.

There is no evidence of outstanding varietal resistance to golden nematode. Early planted potatoes are said to escape nematode attack to some extent by making growth before soil temperature becomes favorable to nematode activity.

Rotation of crops is of small help in this case because of pronounced cyst longevity. Where the parasite persists in soil for eight or ten years ordinary rotations are scarcely practical.

Methyl bromide fumigation of tuber lots has been tried, but tuber injury is encountered before a dosage rate lethal to the nematode is reached. Chemical dips and tuber washing and brushing methods are being explored. While any successful method of tuber treatment would aid the grower to move his crop without endangering other areas, all such methods tend to discourage nematode control in the land itself, an attitude neither serving the grower's future interest, nor representing sound national policy.

It will be seen from this outline of the situation that quarantine action could not at present consider eradication, except through a long-time starvation procedure, but could undertake to prevent spread by regulation of carrier materials--potatoes; tomato plants; root crops grown on

infested soil; nursery stock, and other plants; topsoil and other soil lots; trucks, bags, crates and containers including railway cars; and local transfers of farm implements and equipment. Further, because of the populous semi-urban conditions in the golden nematode area the opportunities for spread are vastly greater than in a purely rural setting; to offset this increased danger it has been considered wise to reduce infestation at source by taking infested land out of potato production and by suppressing nematode populations in infested fields through chemical treatment.

Theoretically, quarantine action of the type here indicated, where the immense potato industries of numerous States were threatened by a destructive but still sharply localized pest, would call for a Federal interstate quarantine, supplemented by parallel action by New York State. This step was duly considered. It was clear, however, that because of the isolated character of the infested center on Long Island, and the measures that New York would be forced to adopt to protect its other important potato districts, that the State quarantine could serve for the protection of other State interests as well as its own. This arrangement has been accepted by general agreement and no Federal interstate quarantine on account of golden nematode has been issued.

Absence of a Federal quarantine connotes no lack of Federal interest in the nematode problem. Federal agencies have cooperated throughout to the fullest extent in matters of research, survey, control, soil treatment, and in the enforcement of quarantine regulations.

It should be added that State quarantines excluding potato shipments from the area under quarantine in Long Island were promulgated in 1947 by Maine, New Hampshire, and Vermont.

The relations of plant pathology to this situation have been and will continue to be important. While earlier European research was invaluable in establishing essential features for quarantine (7), it has been necessary to carry out investigations here in connection with still doubtful relations or those basic to quarantine or control practices. The Division of Nematology has given outstanding service in this field, in close cooperative relations with the research staff of Cornell University and the New York Experiment Station. In the golden nematode studies undertaken by these agencies, helpful cooperative contributions have been made by the Bureau of Entomology and Plant Quarantine, and the New York State Department of Agriculture and Markets. Important additions to knowledge obtained from these investigations include: life history and soil population studies; host range and susceptibility; the development of practical survey methods; exploration of field soil fumigation possibilities; search for effective tuber treatments; and the working out of more rapid and practical methods of cyst identification.

In the golden nematode problem, quarantine and control features seem to be closely interwoven. In both fields future success in preventing spread and providing control methods will demand extensive and patient research. Soil fumigation, and with it field control is not yet on a satisfactory basis; survey methods are much in need of improvement; tuber treatments should be more extensively studied; and the possibility of climatic limitations, important for southern potato areas, has yet to be explored.

Larch Canker

The larch canker disease due to the fungus, Dasyscypha wilkommii, has long been a noteworthy handicap on larch plantings in northern Europe, and great alarm was felt when this parasite was found to be present in larch plantings in three localities in southeastern Massachusetts and Rhode Island in 1927.¹⁵

Consideration was immediately given to quarantine action for this disease on account of the possibility that it might be carried west and there attack the highly valuable stands of Douglas-fir. European investigations had seemed to show that the true larch canker fungus and the closely related Dasyscypha calycina were merely varieties of a single species. The latter was common on bark of the rough-barked pines, larch, and Douglas-fir in localities where the undoubtedly parasitic canker fungus D. wilkommii was obviously attacking larch. Hence, there was a natural apprehension that the immensely valuable forests of the Douglas-fir in the West might be subject to attack by the larch canker organism.

However, special investigations on the larch canker situation in Europe by G. G. Hahn in 1928 and 1929 indicated that the Dasyscypha species found there on Douglas-fir differed from D. wilkommii and was evidently a weak parasite; he regarded it as a distinct species (D. calycina). The true larch canker fungus did not appear to cause cankers on the Douglas-fir in Europe.

¹⁵S. R. A. 1928, pp. 27 and 110.

Further studies by Hahn and Ayers (21) of the several *Dasyscypha* species present in the New England larch canker area disclosed the existence in Douglas-fir cankers of a native large-spored *Dasyscypha* (*D. ellisiana*) closely related to the true larch canker organism but determined by inoculations to behave as weak fir parasite. Inoculations in 1931 on Douglas-fir with the true larch canker species, with two other native *Dasyscypha* species, and with *D. calycina*, produced no cankers and it was confidently concluded that the larch canker fungus need not be feared as a Douglas-fir pest.

In the meantime prompt and energetic action taken by the two States concerned¹⁶ promised effective elimination of the cankered larch plantings, and this work was virtually completed in 1932-33. Since no other infected centers were known Federal quarantine action was deferred, and when the above-mentioned research results had cleared up larch canker relations and removed the threat of damage to the Douglas-fir, the primary reason for quarantine action no longer existed and no quarantine measures were adopted then or since.

It is recognized, however, that the disease still remains a potential danger to larch plantings, and if larch should in future come into more prominence as a timber resource, control of canker and quarantine measures to prevent its spread might have to be given consideration.

Phony Peach and Peach Mosaic

Although phony disease was observed on peach in Georgia as early as 1885-1890, it was not recognized as a specific malady until about 1920 (42), and its virus character was not established until 1929 (28). Later, it was found to affect plum, apricot, nectarine, and almond. A chemical test for this virus was developed, and the incubation period was roughly determined as about 18 months or more (29). With this meager background of knowledge and the assumption that rogueing methods would be as successful as a control measure as they had proved in peach yellows, a campaign aiming at eradication was begun in 1929, supported by a domestic plant quarantine intended to prevent interstate spread through control of nursery stock shipments. Because of failure to secure infection by bud-grafting methods although root grafts readily transmitted the disease, it was concluded at that time that the virus was carried only in the root system and that nursery bud sources were a negligible element in preventing spread. On this basis the protection of nurseries was thought to be secured by keeping the nursery and the environs within one mile free from phony-infected trees.

In the absence of exact knowledge the fixing of this zonal radius at one mile represented largely an arbitrary judgment derived mainly from experience with peach yellows. This mile-zone feature has, however, been continued in the program to date; adequate knowledge on the distance of spread is still unavailable.

More recent investigations, however (32), have indicated that under some conditions the phony virus may be present temporarily, at least, in some of the foliar terminals, so that spread by twig-feeding insects can no longer be held incompatible with the root restriction above mentioned. Still other recent results (31) associate the phony virus with the woody cylinder; some portion of the vascular layer must be included with grafting or budding operations to insure successful transmission. When this relation is recognized, bud transmission has been obtained in some cases even from aerial parts of the tree.

The phony peach Quarantine No. 69, effective June 1, 1929¹⁷, established regulated areas in Georgia and Alabama, and prohibited shipment from them of nursery stock except when grown in nurseries maintained under mile-zone phony-free conditions.

Surveys in subsequent years up to 1931, however, disclosed a widespread though less intensive occurrence of the phony disease in other States, and effective November 30, 1931, the quarantine was extended to cover all of Louisiana, Mississippi, and South Carolina, as well as parts of Arkansas, Florida, Illinois, North Carolina, Tennessee, and Texas. A continuation of survey in 1932 brought to light phony infections in Missouri and Oklahoma. This wide distribution of the disease so altered the situation that after a conference December 13, 1932, it was decided to revoke the Federal quarantine. This was effective March 1, 1933¹⁸, although it was understood that Federal cooperation would be continued in matters of survey, research, control, and eradication.

With the revocation of Quarantine No. 67 responsibility for preventing interstate spread reverted wholly to the States, and although Federal cooperation was freely extended to the several States in their nursery and environs inspection problems, the phony control situation was not put

¹⁶S. R. A. 1929, p. 8.

¹⁷S. R. A. 1929, 118-123.

¹⁸S. R. A. 1933, 147-149.

on a generally satisfactory basis until 1936, when it was combined with the peach mosaic problem, as discussed further on.

Peach mosaic was recognized as a new virus trouble in peach in 1931 when cases coming to attention in Texas orchards were studied by L. M. Hutchins and determined by budding and grafting methods to be of virus nature (30). In 1934 the disease was reported from Colorado by E. W. Bodine (5). Since then survey has located peach mosaic in California (1933), Utah (1936), New Mexico (1936), Arizona (1936), Oklahoma (1937), and Arkansas (1947). It is known to occur also in northern Mexico.

Investigations of the relations of peach mosaic have produced evidence of the occurrence of mosaic in cultivated plum, nectarine, apricot, and almond, as well as in wild plums; some of these hosts as well as some peach varieties show transient, vague, or uncertain symptoms and may thus serve as symptomless carriers; the mosaic virus is regarded as comprising several different strains; and while an insect vector is strongly indicated, vector relations are still too indefinite to serve as a confident guide in either quarantine or control activities.

No Federal quarantine has been promulgated on peach mosaic. In 1936 Federal cooperative relations and the conditions in the various States concerned with both mosaic and phony peach were subjected to thorough review and an attempt was made to establish a single but comprehensive regulatory and control program in which each of the States and the Federal agency could participate, and which would serve alike the interests of the Federal government, the States where these diseases occurred, and the uninfected States needing protection against spread.

It may be noted that the phony peach and peach mosaic problems are very similar in that they both involve the possibility of spread by nursery stock; both require rather widespread survey activities to provide current information on incidence and spread; and in both experienced technical assistance has to be rendered to orchardists in the matter of commercial orchard control. At least two of these phases--prevention of interstate spread and survey--are to a large extent Federal responsibilities.

Federal and State resources have by general agreement been pooled in conducting nursery inspection, orchard inspection and survey as one program, jointly planned but directed by the Federal agency on account of the need for integrating these activities over a number of States. The prevention of interstate spread, essentially a matter of nursery stock supervision, could have been solved in any one of three ways: 1 -- by the promulgation of a Federal interstate quarantine on the movement of host nursery stock from the affected States, supplemented by quarantines of intrastate character by these States to take care of their own internal needs; 2 -- by an arrangement whereby the Federal authority would refrain from quarantine action, leaving the protection of uninfected States to be obtained through whatever individual quarantine measures these States wished to take, in which case the infected States would likewise be obliged to take care of their own internal protective needs and the Federal agency would enter into the situation only as an interested cooperator; 3 -- by adoption of the same cooperative relation on the part of the Federal agency, but with effective quarantine measures set up only by the infected States, the outlying States agreeing to accept such an arrangement as according them adequate protection against spread.

It is obvious that the third method is not only most economical in operation but involves the least disruption of trade practices or interference with movement. It thus represents a higher plane of quarantine efficiency, and where it can be used to advantage it is to be definitely preferred. It demands, however, careful management, the confidence of the protected States, and the deep interest and cooperation of the Federal agency if it is to succeed. This method of approach to the interstate quarantine problem was used long ago in the citrus canker campaign, again in the potato wart problem, still more recently in the golden nematode plans.

This third method of putting into effect the regulatory features of the peach diseases program was selected and widely approved in 1936 as the simplest and most feasible means for the prevention of spread in this case. It may be added that it has worked well and that there has been yet no evidence of interstate spread through the movement of nursery stock in either the phony peach or mosaic areas.

In the current peach disease project, therefore, prevention of spread, orchard control, and survey functions are inextricably interrelated. The experienced inspectors contributed by both the Federal agency and the infected States are utilized under Federal supervision according to the season in the inspection of nurseries and their one-mile environs, as well as of budwood sources and their environs in the mosaic areas. Later these inspectors examine commercial orchards and mark diseased trees for removal, and as opportunity offers, inspection of the survey type is made in outlying areas to keep a check on phony and mosaic development outside of the known infected territory.

A report is made by this inspection service on the disease conditions found in and around nurseries and budwood sources in each State, and this report is the basis on which the State grants or withholds the certification required under the general arrangement for interstate nursery stock movement.

In summarizing the regulatory aspect of this phony peach and peach mosaic project, several features stand out clearly--the absence of a Federal quarantine; the adoption of a practically uniform series of quarantines by the affected States; the close cooperation of the Federal agency with each State concerned, not only in its regulatory control of nursery stock intended for interstate movement, but in orchard control and survey activities as well; and the avoidance by numerous other peach-growing States of the need for a host of individual State quarantines diverse in content and difficult to enforce effectively.

A recent very important contribution in the phony peach problem (54) establishes as phony vectors at least three insect species in the leafhopper group. This accession to knowledge not only throws light on a key feature of this perplexing disease but also indicates likely paths for other research efforts, which in turn may profoundly benefit the future control program.

Vector relations in peach mosaic are still under investigation. Tests conducted at the Colorado Agricultural Experiment Station (13) indicate that the green peach aphid (Myzus persicae) may be at least one effective agent of mosaic transmission.

From the pathologist's viewpoint these peach virus diseases still need much investigation to put control and regulatory features on a sound footing. More light is urgently needed on host ranges, reservoir hosts, symptomless carriers, vectors and their relation to spread, season, and mode of infection, and virus strain relations.

Powdery Scab Quarantines

The powdery scab organism, Spongospora subterranea, was known to exist in European countries at the time of the passage of the Plant Quarantine Act in 1912, and steps were taken (Quarantine No. 11, effective December 30, 1913) to exclude foreign potatoes on account of this and other pests.¹⁹ Late in 1913 the powdery scab disease was found on potatoes in Maine in a limited area near the Canadian border. A conference on this situation was held in Washington, February 26, 1914, and arrangements were there concluded to have Maine control this still very limited outbreak by a system of State inspection and certification. However, more powdery scab soon began to appear in Maine, and on April 25, 1914, a Federal Domestic Quarantine (No. 14) was imposed on the State.²⁰ Still further search disclosed powdery scab in northern New York and that State was likewise placed under a similar quarantine on November 14, 1914 (No. 18).²¹ Federal regulations to govern the movement of potatoes out of the quarantined areas of these two States were set up, involving a system of inspection and certification.

Knowledge on the nature of the scab organism and its distribution was woefully deficient up to that time, and we must understand that the quarantine action thus taken so promptly represented a sincere effort to protect the country's interests under apparently threatening circumstances.

Extensive survey activities were undertaken immediately and these disclosed little or no powdery scab outside cool northern areas. Evidence was rapidly accumulated also which established the inability of the parasite to survive under warm southern conditions; seed potatoes well infected with powdery scab could be shown to produce a clean crop in a warmer environment. Consequently a rapid change in attitude took place. Instead of regarding these northern outbreaks as dangerous recent invasions from Europe likely to spread devastatingly, they soon came to be looked upon as probably long-existent centers naturally confined to colder areas, and hence relatively harmless to the rest of the nation's vast potato cultures.

As soon as these relations were reliably established, both powdery scab quarantines (Nos. 14 and 18) were promptly revoked by an order of August 30, 1915, effective September 1, 1915.²²

This early quarantine attempt demonstrates clearly the need for adequate pest information as a sound basis for quarantine action and emphasizes also the difficult quarantine decisions that an administration may be compelled to make in the absence of sufficient knowledge.

Potato Wart

The potato wart organism (Synchytrium endobioticum (Schilb.) Perc.) was probably introduced into this country in several shipments of European potatoes imported in the winter of 1911-12 to relieve a temporary crop shortage in the Eastern States. These were widely distributed in these States, mostly to heavy population centers. Some of these potatoes were doubtless

¹⁹S. R. A. 1914, p. 9. ²⁰S. R. A. 1914, p. 19; p. 31. ²¹S. R. A. 1914, p. 82. ²²S. R. A. 1915, p. 57.

planted or their peelings and waste found their way to town and village gardens, thus establishing scattered wart infections in local soil over a wide area. When wart was discovered in Pennsylvania in 1918 (47) extensive surveys indicated its presence in many counties of that State and in limited portions of West Virginia and Maryland (35). Although the original European shipments had been widely distributed elsewhere, wart was found to be confined to cold mountain top areas, largely non-agricultural, thus raising the suspicion of a climatic limitation.

European experience indicated the existence of varietal resistance amounting to practical immunity, and several widely grown American potato varieties were soon found to possess a similar immune character. Being entirely soil-borne, wart could be spread only by human activities involving movement of infected tubers or contaminated soil. In Europe the wart disease had been seriously destructive to susceptible potatoes and infested the soil for many years.

The potential threat of such a disease to our second important national food crop was recognized early, and Orton and Field in 1910 (44) made an urgent plea for the exclusion of European potatoes to prevent its introduction. This dangerous situation was so well understood by responsible State and Federal leadership by 1912 that there was included in the Plant Quarantine Act passed that year a provision for immediate quarantine action against potato wart, along with white-pine blister rust and the Mediterranean fruit fly. Foreign Quarantine No. 3 on this disease was thus issued effective September 20, 1912, before the general effective date of the Act itself on October 1.

Upon discovery of potato wart in 1918 in the three States mentioned, the question of a Federal domestic quarantine to prevent interstate spread was immediately considered. Before such action could be taken, however, it was necessary to conduct a widespread and intensive survey based largely on available records of the 1912 European potato distribution destinations.

As survey results built up a picture of an unexpectedly limited wart occurrence, and as the energetic action undertaken by the three affected States appeared to promise ample safeguards in the relatively simple problem of preventing spread, either locally or to other States, the need for Federal quarantine action seemed less and less imperative. The final outcome of these developments was a general agreement to forego a Federal quarantine and to rely on adequate State quarantines carried out with Federal assistance and cooperation. This policy has continued unchanged to date.

The quarantine attitude adopted in this case represents an early example of the increasing present tendency to depend wherever possible on the quarantine and regulatory efforts of a State to prevent spread of a specific pest, both within its own borders and to other States, rather than to rely on measures in the State of destination or on Federal interstate quarantines.

This preference for local action in Federal-State quarantine relations, wherever State measures can adequately meet the situation, does not signify Federal disinterest or lack of cooperation in such problems. Outside of purely quarantine aspects the Federal agencies may still participate actively in research and survey activities, as well as generally looking after the interests of other States likely to be affected. This has been the Federal role in potato wart.

Contributions in the field of plant pathology which have materially affected quarantine plan and procedure have been many and varied. Many pathologists in Federal and State agencies and institutions participated in the extensive early surveys for this disease. Since then survey has been continued in the affected States by State effort, particularly in Pennsylvania where a large part of the State has been systematically examined for wart over the years. No evidence has appeared which would indicate that distant spread has taken place from the areas under quarantine (2).

Early interest in the utilization of immune varieties led to the testing of all available commercial American potato varieties (22, 23), as well as some of the more promising European sorts. Further, all new varieties developed by the Bureau of Plant Industry, Soils, and Agricultural Engineering are tested for their relation to the wart disease as a routine procedure. These tests involve planting for a season in garden soil in Pennsylvania kept heavily infected with the wart organism, under the supervision of the State's wart control personnel.

The great longevity of the wart organism in soil has been indicated by observations in Europe and in this country. Field observations and experiments have been conducted in Pennsylvania since 1927 by the State Bureau of Plant Industry to determine how long wart will persist in soil under various cultural conditions. These studies were summarized at the end of 1949 by R. E. Hartman, pathologist, in charge of wart control activities for Pennsylvania during this period:

"There appears to be no definite period of wart persistence in soils. Our records in Pennsylvania indicate that, while wart is known to have survived for 25 years in one case in land under permanent sod, the organism disappeared in 10 years from an

experimental plot maintained in sod and tested annually for wart persistence. Where the soil is cultivated yearly or kept under fallow conditions, wart seems to die out more rapidly--in 6 seasons in several experimental plots, and apparently in similar periods in gardens planted to vegetables or with immune potato varieties. It is suspected that the available oxygen supply is a factor in hastening spore germination in soil and thus reducing longevity."

Survey indications of a wart relation to low soil temperatures have been confirmed by a series of soil temperature records carried out for several years in Pennsylvania and by potato inoculation tests made there under various constant temperatures. The results place the upper limit for wart persistence at about 70° to 72° F. This permits a general correlation of wart with areas having a frost-free growing period of 140 days or less. This relationship indicated on a map of the United States will suggest those areas where potato wart is likely to persist (36).

An early phase of investigation attempted to develop practical heat and chemical soil treatments for infected garden plots. Many of these successfully killed out the wart organism (55).

Reports from German sources (6) indicate the presence there of biologic races of the potato wart fungus which are said to attack some of the potato varieties normally regarded as immune. Since the only practical field control of potato wart lies in the fortunately ample list of known immune varieties (22), the ominous implications of this race plurality deserve the close attention of pathologists.

The outstanding feature of the potato wart situation is the eradication campaign well on the way to completion in Pennsylvania (35) and now initiated in both Maryland and West Virginia. A number of methods of destroying the wart organism in infected soil were developed at the outset (27), but none of these could be put into effect on a field scale until the distribution of wart was more certainly determined by survey. This stage was reached for the Pennsylvania wart situation about 1930. Since then a long-time highly successful program for the suppression of wart in successive areas has been undertaken. Present prospects are for its completion in the State by 1952. The Pennsylvania program takes advantage of natural wart disappearance from the soil and the abandonment or obliteration of many infested gardens in coal mining operations; in addition gardens are treated with about one ton per acre of copper sulfate, which has proved practical and effective for eradication purposes. To effect the elimination of a soil-borne organism of this persistent type from such numerous individual gardens scattered over a large area is an unusual and distinctive accomplishment.

The wart problem presents another feature of interest to pathologists. A special committee of the American Phytopathological Society appointed to study plant disease matters of quarantine interest has been asked by the Bureau of Entomology and Plant Quarantine to examine the wart situation and present suggestions and recommendations on plant quarantine policy and relations.

White-Pine Blister Rust

The pronounced susceptibility of our American white pine species (*Pinus strobus*) to the white-pine blister rust (*Cronartium ribicola* Fischer) was well established in the closing years of the last century by observations in Europe, where this excellent timber tree was being tried out by progressive European forestry organizations. Because of abundant occurrence there of the necessary alternate hosts (*Ribes* spp.) and particularly the very susceptible European garden black currant (*Ribes nigrum*), damage to white pine nursery stock and planted seedlings was so severe as largely to discourage the use of this otherwise very desirable timber species.

Reports in European journals and urgent warnings issued by forest pathologists returning from European visits served to drive home the impending threat of devastation to one of our most valuable timber resources should this disease become established in America. At that period much effort was already being directed to reforestation of the extensive eastern areas where forest wealth was rapidly vanishing because of fire losses and reckless and destructive utilization.

While these earnest warnings stirred little popular feeling on the subject they were effective enough among thoughtful and farsighted leaders, and the discovery of the disease here in 1906 aroused sufficient interest to have the white-pine blister rust included as a prominent reason for passage of the Plant Quarantine Act in 1912. In fact, that Act included a special provision for immediate promulgation of quarantine protection in the case of blister rust and potato wart. The Act in general became effective October 1, but quarantine action on these two subjects was permitted immediately after the date of passage August 20, 1912.

This step toward exclusion was too late, however; the rust was already in the country, having

apparently been introduced in large shipments of nursery seedlings of white pine and widely distributed in a number of Eastern States and adjacent parts of Canada. From a number of independent rust centers thus started, local and distant spread has disseminated the fungus into practically all commercially important white pine areas. It became and still remains a domestic plant quarantine problem.

The first Federal Domestic Quarantine on white-pine blister rust (No. 26) was promulgated, effective June 1, 1917. It quarantined all States east of and including Minnesota, Missouri, Arkansas, and Louisiana, and prohibited the movement of five-leaved pines or currant or gooseberry plants out of the quarantined area; it further prohibited movement of five-leaved pines or black currants out of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, and New York--the area then regarded as actually infected.

At this time hopes were entertained that it might be possible to delay or prevent extensive spread of the blister rust, and to control it locally in the infected portions of eastern forest areas. Protection of the western white pine areas was also regarded as imperative, and the restrictions on shipment from the quarantined Eastern States were intended to prevent spread into the Pacific region.

Delay in establishing a domestic interstate quarantine until 1917 arose from a defect in the original Plant Quarantine Act which prevented the application of Federal quarantine regulations to a portion of a State.

The necessity of considering the State as a unit in any Federal action so that quarantine restrictions applied alike to infected and uninfected areas within it, involved such obvious injustice and hardship to noninfested areas that establishment of a workable quarantine measure had to await a revision of the Act on March 4, 1917, which permitted restriction of the regulations to State areas actually affected by the pest, and designated as regulated or control areas.

The discovery of blister rust in southern British Columbia and in nearby Washington State late in 1921 made real the previous potential threat to the white pine areas of the West. An additional quarantine, No. 54, effective March 15, 1922, was promulgated to protect Washington and other Western States from spread out of the then known 19 infected counties of Washington. The evidence indicates that this west coast outbreak did not arise from numerous introduction centers as in the east, but was traceable to one lot of diseased white pines imported from Europe into British Columbia in 1910.

In subsequent years extensive spread took place in both East and West, and it was soon recognized that blister rust would eventually reach all susceptible white pine areas where the ribes hosts were present because of the wind-borne nature of the rust. To accord with this viewpoint the quarantine aims and procedures underwent some modifications which were embodied in a single new Nation-wide measure, Quarantine No. 63, effective October 1, 1926. This quarantine amalgamated Quarantine No. 26 with Quarantine No. 54, and extended the scope of the combined measure to include the entire continental United States. It retained the provisions for protecting still unaffected areas in both East and West against rust introduction by host movement in advance of natural spread, but in general it geared its restrictions and requirements to supplement and serve the needs of the nation-wide control program based on elimination of ribes hosts growing near pines.

Further revisions were made in Quarantine No. 63 or its regulations, effective July 1, 1938 and on July 1, 1946. These introduced certain procedural changes and modifications helpful for administrative purposes, but they have left essentially unchanged the basic relation of the quarantine and its regulations to the control program.

The progress already made toward protecting the country's white-pine timber resources from blister rust damage represents a high national achievement in the pest control field. In spite of the gloomy prospect which faced us a quarter of a century ago, white pines, our most highly prized forest trees, are now reseeding and flourishing over thousands upon thousands of acres which once seemed doomed to produce only inferior forest species. Regarded in proper perspective the time, money, and effort spent in this large-scale control undertaking will pay off handsomely to the Nation in the years to come.

The part played by regulatory features in this program has been largely supplementary, not dominant. In a true sense the blister rust campaign throughout its course has been a community effort, not solely a Bureau project. It would have been impossible without the generous assistance of numerous States, the contributions of many counties and municipalities, the cooperation of forestry and lumber interests, the public-spirited attitude of innumerable community leaders, the willing participation of a host of individual land holders large and small, and especially the invaluable contributions of many plant pathologists in Federal, State, academic or private service all over the country.

It may be appropriate here to review briefly some of these contributions which have had important influence on the quarantine viewpoint. It is impossible in this limited article to list the numerous contributions in this field; mention can be made only of research features which have importantly furthered quarantine understanding and bettered procedures. Reference may be made, however, to the extensive compilations of literature prepared by Spaulding (49, 50); by Fulling (15); and by Mielke (39), the last named dealing especially with the blister rust problem in the Western States.

The recognition about 1916 of the weak and localized nature of spread of the ribes sporidia to pines had obviously a most important bearing on the situation. Determination of the effective sporidial range underlies not only the extent of the ribes-free zone needed for pine protection but also enters directly into the problem of white pine nursery production.

Of almost equal importance were the studies and observations on wind dispersal of urediniospores and aeciospores which, along with numerous infection experiments, established relations of extremely practical value in field control plans.

Host species range and species susceptibility had to be worked out for both pine and ribes groups. Studies of the weather conditions under which pine and ribes infections occur, together with the later course of development of such infections, supplied information of great practical control value. The conclusion reached early that the ribes rust stage may for all practical purposes be regarded as nonwintering on this host had a material effect on both control and quarantine planning.

Contributions to our knowledge of survey methods have been numerous. These have tended definitely to increase efficiency or to lower costs of operation. Careful studies of ribes habitat, species peculiarities, methods of eliminating these hosts cheaply and completely, have been invaluable to the program. Of special interest have been investigations on seeding habits, root-sprouting behavior, checking on ribes recurrence, and the use of herbicidal chemicals in eradication work.

Woodgate Rust

The Woodgate Rust Quarantine No. 65 was imposed, effective November 1, 1928, on nine counties in northern New York to prevent spread of this gall-forming rust (*Peridermium* sp.) from the only region then known to be attacked by this parasite on Scotch pine (*Pinus sylvestris*) and other hard pines. Concurrent with this quarantine, regulations were issued which in effect prohibited movement out of the regulated area of trees, branches, limbs, and twigs of Scotch pine or other hard pine species.

This action was taken, it was stated, not so much to protect the particularly susceptible Scotch pine in plantings elsewhere, but to prevent spread of this damaging disease to other hard pine species of the Southern and Western States. While less subject to infection than Scotch pine, various other hard pines were much more valuable timber trees.

This quarantine continued in effect until July 31, 1939, on which date it was revoked together with its regulations. It was then explained that several years of observation indicated that this rust did not spread aggressively and that its threat to the country's hard pine species did not seem serious enough to warrant continuation of the quarantine.

From the point of view of plant pathology the Woodgate rust situation presents certain features of interest. This rust was found in the vicinity of Woodgate, New York, in 1925, on Scotch pines. These showed in some cases a heavy gall production which evidently interfered with normal tree development. Annular ring studies of gall tissue indicated a long-standing infection. The galls of Woodgate rust can be distinguished only with difficulty from those common on Scotch pine due to *P. quercina* (= *P. cerebrum*). Survey thus becomes largely a technical operation. It was established, however, that infection could take place from the pine aecial stage directly to other pines; no alternate host is concerned. Inoculation studies on other hard pines gave rather poor results and a low rate of infection in general.

Many of these features and relations came to light subsequent to the promulgation of this quarantine. But however much these later contributions may have clarified knowledge of the Woodgate rust situation, the chief weakness of the quarantine did not lie in these unknown biological factors so much as in the poor adaptation of the quarantine plan to its intended objective. There was, it is true, one nursery in the regulated area likely to grow and sell pine trees; its activities could readily have been controlled by the State in the normal course of nursery inspection routine. Aside from this means of rust dissemination there remained only two channels: 1 -- the carrying away of trees, limbs or branches by casual visitors; 2 -- wind dispersal of spores. The latter was entirely outside of quarantine control, since no attempt to suppress galls

or aecial formation in the infected area was included in the program. As far as trees and gall-bearing limbs were concerned, these seldom or never moved in public carrier channels where quarantine control would be effective. Any movement of such materials interstate would almost invariably involve occasional and wayward transport by private individuals, and over this type of movement no effective supervision was provided.

In this case, therefore, the quarantine was soon found to have a low protective value, not primarily because of any lack of technical knowledge, but because the quarantine procedure itself could accomplish little in a practical way in preventing spread.

The situation ten years after the revocation of the Woodgate rust quarantine has tended to confirm the apparent inertia of this rust and to class it as a pine disease of sluggish habit and minor importance.

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DIVISION OF DOMESTIC PLANT QUARANTINES, BUREAU OF ENTOMOLOGY AND PLANT
QUARANTINE, AGRICULTURAL RESEARCH ADMINISTRATION

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The Georgia Experiment Station was established August, 1888, and plant diseases were among the first agricultural problems to receive attention. This may appear surprising, since in public institutions, such as the State agricultural experiment stations, fields of research nearly always follow rather than precede public interest.

Brief perusal of agricultural publications prior to the establishment of the experiment station shows real farmer interest in plant diseases even at an earlier period. The Central Agricultural Society (changed to Georgia Agricultural Society in 1852) held a fair each year with valuable prizes for the best exhibit of each agricultural product, and required the grower to report the variety and the method of growing the crop. In compliance with this requirement in connection with an exhibit of wheat, about 1850, D. Ponce reported that the seed was soaked 12 hours in bluestone solution, one pound bluestone to five bushels of wheat, drained, spread on a floor, and dusted with hydrated lime. Numerous references to losses from black rot of grapes, rots of peaches and of apples, and from various other plant diseases, with occasional reports on attempts to control them, are recorded in the "Transactions" of this society.

In view of this farmer interest, it is not surprising to find the very first experiment station staff devoting considerable effort to obtain better control of plant diseases. They were not trained pathologists, but their work in pathology deserved the research designation perhaps as much as that in other lines at that time. Gustave Speth, the first horticulturist, published in 1891 a bulletin on small fruits with a single page devoted to diseases. The following year, he published one on culture of sweet potatoes with a report (two pages) on attempts to control black rot, and one on tomatoes with a three-page report on fruit rot (blossom-end rot). He was succeeded as horticulturist in 1893 by H. N. Starnes who published on diseases of grapes, diseases of Irish potatoes, and diseases of blackberry and dewberry; but these reports contained no experimental data. However, a report on peach maladies did contain experimental data on the effect on peach foliage of Bordeaux mixture at varying concentrations and with varying proportions of Paris green or of London purple added. In January 1899, Starnes was succeeded by A. L. Quaintance, with the title of biologist and horticulturist. Quaintance remained less than three years, but in this time did an enormous amount of experimental work on control of insect pests and diseases along with the general work with horticultural crops. He published a synoptical, tabular description, including relative susceptibility to black rot, for 302 varieties of grapes, and short articles in the Annual Reports summarizing work on control of grape black rot, Macrosporium blight of tomato, and on celery blight. His bulletin on brown rot of stone fruits was a more extensive contribution.

Quaintance was succeeded, in October 1901, by S. H. Fulton, who remained less than a year, but completed and published a study of cantaloupe varieties and diseases that had been started by Quaintance.

On August 15, 1902, H. N. Starnes returned to the station and in 1904 and 1905 published two bulletins on plums, including considerable discussion of diseases in each.

Following passage of the Adams Act in 1906, a Department of Botany and Plant Pathology was established, and R. J. H. DeLoach was appointed to head the department on January 1, 1907. DeLoach remained less than two years, but published a bulletin on cotton anthracnose.

He was followed in October 1908, by C. A. McLendon who remained until October 1913. McLendon devoted full time to cotton breeding and carried no research in plant pathology. During this period, J. M. Kimbrough, agronomist, reported that adequate potash applications greatly reduced incidence of so-called cotton rust, thus indicating the disease to be due to potash deficiency. Also, H. P. Stuckey, horticulturist, and J. C. Temple, bacteriologist, cooperated in a study of tomato blossom-end rot, which demonstrated for the first time the real cause of the disease to lie in the water relations of the plant. They were also interested in and had started preliminary investigations to determine the etiology of plum wilt when B. B. Higgins came to the station as botanist and plant pathologist in October 1913, and the problem was turned over to him.

About the turn of the century, interest in commercial plum growing was almost as great as that in peach growing. In 1904, nearly a million trees were reported in Georgia orchards; but by 1913 the industry was practically dead and most commercial orchards had already been abandoned, owing to plum wilt, bacterial leaf-spot and canker, and cold injury, wilt being far the most serious. It was hoped, therefore, that an understanding of the disease might suggest practical control measures that would allow the industry to become reestablished. However,

finding that the disease was caused by a fungus which could, and did persistently, enter through pruning wounds, borer wounds, cankers from cold injury, or any wound which admitted the fungus to the heart wood of the tree; did not suggest any practical method for controlling it.

The conspicuous gum exudation and the relation of gum formation to spread of the causal fungus through the tree led to a study of gum formation and wound healing of woody plants in general.

During this period several minor problems were investigated: diseases of collards, a microstroma disease of pecan catkins, the value of spraying Irish potatoes under Georgia conditions (with hopper burn and early blight the principal diseases), resistance to nematode in peaches, resistance to blight of Pineapple pear, and rosette of peach.

During the period of the first world war, the pimiento canning industry was developing about Griffin, Georgia, and by 1920, a considerable acreage was grown under contract in this area. Little was known about diseases; no disease control measures were used in the plant beds, in the fields, or in the cannery where seed were saved; consequently, losses were severe. In an effort to help an infant industry, an intensive study of pepper diseases was begun in 1920, studying the etiology, and the control of all diseases occurring locally. The diseases found sufficiently destructive to justify control measures were: damping-off, southern blight, mosaic, *Cercospora* leaf-spot, bacterial spot, anthracnose, and blossom-end rot. Later (1929) a fruit rot caused by *Vermicularia capsici* Syd. was observed in the area about Macon, Georgia, and was described under the name "Ripe rot." It has now spread over the entire State and, during rainy seasons, is the most destructive of all pimiento diseases.

Space will not permit discussion or even mention of studies of the various diseases and control measures indicated from these studies; but the fact that seed treatment was found an effective and cheap method of controlling several of the more serious pepper maladies is of interest. The studies with pepper seed treatments indicated the desirability of treating seed saved from fleshy fruits before drying, if a liquid treatment was to be used. Later this recommendation was found to be applicable to tomato, cucumber, cantaloupe, watermelon, etc., and treatment of the freshly harvested seed of such crops has come to be the general practice among the better class of seed producers. The work with pepper seed also led to cooperative relations between the Georgia Experiment Station and the manufacturers of seed-treating materials. This cooperation was continued through several years and was mutually helpful to the manufacturers and to the experiment station workers. Results from studies and the resultant stimulus for similar work in other institutions on disease control by seed treatment constitutes, probably, the most valuable contribution to plant pathology made from the Georgia Experiment Station.

In 1923, a root disease of cotton came to our attention; and, because of its general distribution, investigation as to its cause and possible means of control were started the following year. The disease symptoms were found to be due to growth of *Fusarium moniliforme* on roots of the young plants. Spores of this fungus were found almost universally present on cottonseed. Treating acid delinted seed with mercuric chloride solution completely destroyed the seed-borne spores and in sterile soil the treated seed produced healthy vigorous seedlings; but in the field plantings seedlings from surface sterilized seed showed 50 to 90 percent infection with *F. moniliforme*, owing to the abundance of the fungus in our cultivated soil. The treatment appeared to destroy seed-borne organisms, including *Glomerella gossypii* and *Bacterium* (*Xanthomonas*) *malvacearum*, as had already been reported by other workers.

In order to surface disinfect cottonseed with a solution, it was necessary to remove all lint from the seed, a job not easily accomplished. Although chemical delinting had been recommended by Barre and others some years previously, growers would not delint their cottonseed with sulphuric acid. Furthermore, we found that delinted seed germinated poorly in cold wet soil. Development of a satisfactory dust disinfectant was therefore made the primary objective in this project. Copper carbonate, the only dust disinfectant commercially available, was found ineffective for disease control and seriously injurious to cottonseed. Numerous dusts were prepared in the laboratory, including many mercury and copper salts precipitated on talc or on finely divided coal dust, various aniline dyes, etc. At the same time the Bayer Company and DuPont Company started submitting, for test, numerous preparations containing organic mercury compounds. By the summer of 1927, the feasibility of controlling seed-borne diseases of cotton by the use of chemical dusts was thoroughly demonstrated. Some of our own mercury dusts and one submitted by DuPont had given perfect control of seed-borne, angular leaf-spot bacteria. These results were reported in two articles published in *Phytopathology*; but the investigation was continued in order to examine the properties of the numerous fungicidal dusts that were being submitted by various manufacturers. By 1931, nearly 100 dust materials had been tested. A few dusts containing mercury were the only ones found to control seed-borne

diseases effectively without reducing viability of the seed. Comparative yield tests throughout these years indicated that the per plant yield of cotton from effectively treated seed was significantly higher than that of plants from untreated seed, because of freedom from disease. Considering effectiveness of disease control, improvement of germination, and cost, 2% Ceresan and another DuPont dust, later given the name New Improved Ceresan, were distinctly superior to all others and use of 2% Ceresan on cottonseed was recommended. After two years further test, New Improved Ceresan was also recommended, with the caution that it would retard germination under certain conditions, especially when used in excess of recommended rate.

Following the demonstration of the possibilities of dust treatment of cottonseed in 1927, pathologists in most of the cotton states started similar investigations and their results supported the Georgia conclusions. In 1936, a Cotton Seedling Disease Committee was organized with more than half the cotton states participating. This committee has continued actively testing all promising new chemical dusts suggested for seed treatment; but to date, nothing has been found that equaled the organic mercurials in effectiveness. However, the widespread interest in this field of work did hasten farmer acceptance of the recommendations, and today cottonseed treatment is routine practice throughout the cotton belt. Yearly, it adds millions to the income of cotton growers through improved stands and increased yields.

During the late twenties, investigations were also carried out on bed rot of sweet potatoes (*Sclerotium rolfsii*), on halo blight of beans and kudzu, and on the diseases of cantaloupe. The latter study was concerned principally with cucurbit downy mildew and a practical method for controlling it. Under Georgia conditions, the cantaloupe crop is severely damaged by downy mildew (*Pseudoperonospora cubensis* (Berk. & Curt.) Rostow) about one year in four, but there was some doubt as to the economics of following a regular spray schedule on cantaloupes. During the study, data were accumulated indicating quite definitely that the causal fungus lives over winter, principally on cucumbers, in south Florida, and is spread up the coast, by winds, during periods of cool humid weather. Several sprays and dusts were tried, but none were satisfactory. Cantaloupe foliage is extremely sensitive to sulfur and all copper sprays and dusts available at that time damaged the foliage and delayed fruit development so much that there was rarely any significant profit from spraying. The information gained during this study has led finally to the current cantaloupe breeding program at the experiment station.

The large-scale field production of tomato and other vegetable plants in the coastal plain of Georgia for shipment to more northern regions got underway in the Tifton area about 1914. Tomato seed were sown about the end of February and, growing slowly over a period of eight weeks, the plants had ample time for the development of disease symptoms before reaching the northern purchaser. After a few years, complaints began pouring in; and by 1925, some of the tomato canning states were threatening an embargo against Georgia-grown plants. Some preliminary investigations by O. C. Boyd, of the State Board of Entomology, indicated that the complaints were due to seed-borne diseases and that the causal organisms were present on the seed furnished the growers. Intensive investigations were started the following year by Frank Van Haltern of the Georgia Experiment Station. He found *Alternaria solani*, *Septoria lycopersici*, *Aplanobacter* (*Corynebacterium*) *michiganense*, and *Xanthomonas vesicatoria* commonly present on commercial tomato seed, some lots producing 40 to 50 percent diseased seedlings. None of these except the *Alternaria* appeared capable of living over in the soil under ordinary methods of handling the plant fields. *Alternaria* was found to live over one year and possibly two years under certain conditions. After four years study, it was found that very satisfactory tomato plants could be produced by saving seed from fields showing a minimum of disease, treating the seed before planting, planting in fields that had not grown a solanaceous crop during the previous two years, spraying at least three times before pulling the plants, and using a few ordinary sanitary precautions in pulling and packing the plants. In 1937, the United States Department of Agriculture established a pathological laboratory at the Coastal Plain Experiment Station, Tifton, and has continued the work until the present time.

During the thirties, several other pathological problems were studied. Oat smut was yearly causing serious losses, because many farmers refused to use the formaldehyde method of seed treatment. A large number of dust and liquid treatments were compared over a period of years and New Improved Ceresan dust recommended in 1936.

The mycorrhiza of pecan roots was studied because of its suspected relation to pecan rosette. Five types of mycorrhizal mantles were recognized and the fungi associated with three of these identified. It was found that healthy vigorous trees always had abundant mycorrhizal roots, while rosetted trees had few feeder roots of any kind and few or no mycorrhizae, although this condition appeared to be a result of the nutritional disturbance associated with zinc deficiency rather than the cause of rosette.

During the winter of 1927-28, cold injury to peach trees was severe. Observations on trees in a fertilizer test indicated that injury was inversely correlated with vigor, being least severe in blocks receiving fertilizer with high nitrogen ratio. Since this observation was not in agreement with prevailing horticultural recommendations, an investigation was initiated in cooperation with the Bureau of Chemistry and Soils, U. S. Department of Agriculture. The results confirmed the original observation and indicated that the best insurance against cold injury lies in maintaining vigorous growth in the trees.

The erratic behavior of cotton varieties in their susceptibility to Fusarium wilt had been a serious problem confronting the cotton breeder as well as the pathologist until injury to cotton roots by meadow nematodes was noted in several Georgia test fields in 1938. In these fields the most wilt-resistant varieties became quite susceptible, and the same behavior was noted when soil of a test field was infested with root-knot nematode and Fusarium. Considerable variation in susceptibility to root-knot damage was found among cotton varieties. This work was done in cooperation with the United States Department of Agriculture in connection with a cotton breeding project.

An investigation of the root-rots of snap beans developed the information that in Georgia snap beans are subject to several root diseases that shorten the life of the plants and caused by: Sclerotium rolfsii, Macrophomina phaseoli, Rhizoctonia solani, and the root-knot nematode Heterodera marioni. The study helped to clarify the relation between Macrophomina and the sterile condition of the fungus known as Sclerotium bataticola, and some valuable information concerning other bean diseases was obtained; but little resistance to these diseases, especially to Sclerotium rolfsii, was found in any variety of beans and the breeding program was soon abandoned.

This brings us to a discussion of the present program of work at the Experiment Station: 1. Peanut breeding and peanut diseases; 2. Diseases of muscadine grapes; 3. Breeding water-melons for resistance to wilt; 4. Breeding cantaloupes for resistance to diseases; 5. Breeding tomatoes for resistance to wilt and root-knot nematode; and 6. Diseases of pasture plants.

The work on peanuts is the oldest and the most extensive of the current projects and a discussion of its development will serve to illustrate the devious turns a research project may take when benefit to the farmer is the principal motivation.

During the late twenties, there were constant complaints to the Experiment Station on the heavy losses suffered because of peanut diseases, principally leaf spots and southern blight (Sclerotium rolfsii). Our experience with seed treatment as a control for cotton diseases led to a study of its efficacy in controlling peanut leaf spot and tests were started during 1928. The results showed that shelling and surface-sterilizing the seed had little effect upon the incidence or severity of leaf spot when the plants were grown in open air. By 1931, peanuts were selling as low as \$30 per ton. The grower could not afford dusting or spraying in the field because of the low acre value of the crop; and the development of disease resistant varieties with nut characteristics to meet market demands appeared to be the only practical solution. Nearly a hundred varieties and strains from all peanut growing areas were assembled and the breeding work was started in 1931. It is still going on an extensive scale. Several hundred foreign varieties have been added to the collection for study, but none have been found to have any marked degree of resistance to either leaf spot or to southern blight. At present, the wild species of Arachis from South America are being assembled and studied as to their possible genetic value. Some of them appear to be quite resistant to leaf spot diseases.

Along with the breeding work, the common diseases have been studied as to cause and control. It was found that there were two distinct leaf-spots produced by distinct species of Cercospora. The life history of each species was followed through, and the ascigerous stage of each discovered and named: Mycosphaerella arachidicola Jenkins (Cercospora arachidicola), and M. berkeleyi Jenkins (Cercospora personata). Following the excellent results from spraying and dusting peanuts reported from Virginia and North Carolina, tests were started with the Spanish variety in 1937. Consistent and profitable yield increases were obtained from dusting with either sulfur or copper-sulfur (10-90) mixture; and, with increase in price of the crop, growers adopted the recommended practices and dusting is now fairly general.

Observations in peanut fields throughout the coastal plains area suggested poor stand as probably the most important factor responsible for low average yields in Georgia; and caused the resumption of seed-treatment studies with improvement in viability and final stand as the objectives. Yield records were obtained indicating that surface disinfection of the seed had no effect on yield per plant, and seed-treatment for peanuts with 2% Ceresan was recommended for improving stand. After further tests, comparing results with several materials, Arasan and Spergon were recommended for use where the dosage could not be measured accurately, since overdosage with 2% Ceresan sometimes injures the seed. When used on good seed stock, the

improvement in germination from Arasan and Spergon treatment is usually not significantly less than that from 2% Ceresan; but with seed of low vitality or seed severely damaged in shelling, 2% Ceresan is usually significantly superior to any other material tested. Arasan and Spergon at the recommended dosages are not very effective fungicides. Their beneficial action appears to be associated with their anti-oxidant properties.

"Concealed Damage" of runner peanuts was first brought to our notice in 1937. It was found to be caused under certain conditions by most any of the common molds present in the soil, especially when peanuts are harvested during periods of high temperature and high humidity.

Much effort has been expended in trying to discover some means of reducing the losses from *Sclerotium rolfsii* in peanuts as well as in other crops; but to date these efforts have not been particularly fruitful. Proper crop rotation preceding very susceptible with immune or less susceptible crops is of some value. Chemical soil treatments are being investigated. One phase of the disease, "Blue-black" discoloration of Spanish peanuts, develops in stacks and even in bins of threshed peanuts, infected with *S. rolfsii*, if moisture remains high for a few days.

Peanuts are damaged by several species of nematodes. An effort is being made to determine the extent of this damage, the species of nematode involved, and possible control measures.

Seedling diseases which frequently reduce stands and the vigor of the young plants are being investigated.

Since 1941 the Office of Vegetable Crops and Diseases, United States Department of Agriculture has cooperated in the peanut investigations.

A study of the diseases of muscadine grapes, started in 1938, has shown that the *Guignardia* causing leaf-spot and fruit flecking of muscadines differs pathogenically from that on bunch grapes, and that at least one other specialized form of *G. bidwellii* occurs in this country. In like manner, a common leaf spot of muscadines, superficially resembling the *Mycosphaerella personata* spot on bunch grapes, is produced by an entirely different species, *M. angulata*. The economics of spraying muscadine vineyards for disease control has not yet been determined satisfactorily and is still under investigation.

Breeding for wilt resistance in watermelons, started in 1936, has resulted in the development of two highly resistant strains: "Georgia Wilt Resistant" and "Georgia Wilt Resistant No. 2". The former was too small to meet our present market demand, and the latter had a rind too tender for shipment. Both have been used in further crosses and the progenies are in process of reselection.

The principal objective in cantaloupe breeding is resistance to downy mildew; but genes for resistance to powdery mildew and to aphid injury became available and resistance to all three have now been combined with high quality of flesh. Yield and shipping qualities are yet to be determined.

The work on diseases of pasture plants, started June, 1949, is primarily related to a breeding program with fescue and white clover.

Numerous contributions on the physiology, life history, morphology, and systematic relationship of parasitic fungi have also come from this institution.

University of Georgia. Members of the staff of the Department of Plant Pathology have carried on some research since establishment of the department, but most of the published work should perhaps be classed as mycological. Several notable contributions on morphology and classification of Ascomycetes have been published.

Among the contributions to plant pathology may be mentioned: peanut seedling wilt, tomato seed treatment, and *Helminthosporium* disease of oats.

Study of the peanut seedling wilt was made in connection with a peanut disease survey made during the summer of 1931. The wilt was attributed to *Fusarium martii* var. *phaseoli*.

In the tomato seed treatment studies numerous samples of commercial tomato seed were examined and the seed-borne fungi and bacteria of pathological significance determined. Determinations were also made as to whether the organisms were internal or merely on the surface. The factors involved in disinfectant injury of the seed were also studied.

The study of *Helminthosporium* diseases of oats is still in progress.

Georgia Coastal Plain Experiment Station: A department of plant pathology was established October, 1947. To date, the pathologist's time has been occupied largely with cooperative testing of disease susceptibility of new varieties and strains of cotton, corn, Sudan grass, and sweet potatoes in connection with breeding projects with these crops; but research on internal cork of sweet potato has been started.

State Board of Entomology: Occasionally, workers in the State Board of Entomology have carried on investigations of plant diseases in connection with their regulatory work, such as:

1. Studies on cotton wilt by I. F. Lewis, 1906-1911. Largely testing varieties for resistance to wilt.
2. Phony disease of peach was described by D. C. Neal in 1920.
3. Study of disease-producing organisms carried on commercial tomato seed, by O. C. Boyd in 1925.
4. Entomologists are at present cooperating with the pathologists and entomologists of the U. S. Peach Disease Laboratory, Fort Valley, Georgia, in the study of phony disease of peach.

United States Department of Agriculture: Plant pathologists of the United States Department of Agriculture have obtained research data, for numerous contributions, in whole or in part, in Georgia. W. A. Orton and F. V. Rand in their publications of pecan rosette mention work at Cairo, Georgia, in 1903. W. M. Scott and T. W. Ayres worked on peach brown rot control in the J. H. Hale orchard near Ft. Valley during 1907 to 1909. The development and use of self-boiled lime sulfur was based largely on this work.

Work on peach scab was carried on at Cornelia during the summers of 1910, 1912, and 1913.

A laboratory for study of pecan diseases was established at Thomasville in 1918. In 1930, it was moved to Albany where a special laboratory and office building was constructed. Pathological work has been mostly related to pecan scab and its control.

A peach disease laboratory was established at Ft. Valley in 1921. Control of brown rot and bacterial spot were studied over a period of years. In 1923, L. M. Hutchins began study of "Phony Peach." He found it to be a virus disease; and, like many other viruses, a baffling field of research. Transmission of the disease was not easy and no natural vectors were found until recently. The work on this disease is being expanded through cooperation of pathologists and entomologists in studying the spread of the disease in nature.

In 1924, a tobacco disease laboratory was established at Tifton in cooperation with the Georgia Coastal Plain Experiment Station. At present two pathologists are employed. The field of investigation has included: downy mildew, damping-off, black shank, root-knot nematode, and southern blight. Root-knot nematode control has been most intensively studied, including studies on chemical treatment of soil and on crop rotations.

A nematology laboratory was also established at Tifton in 1935. At present two nematologists are investigating various methods of nematode (principally root-knot) control. Fumigation and other chemical applications, rotations, and cultural practices are being studied as to effectiveness and cost.

A laboratory for studying diseases of tomato and other seedling plants was established at Tifton, January 1, 1937. At present, two pathologists are employed, studying principally diseases, cultural practices, and methods of handling and shipping tomato plants.

On August 15, 1935, J. L. Weimer was located at the Georgia Experiment Station, Experiment, to study diseases of winter cover crops, principally Austrian Winter Pea and vetch. At that time Austrian Winter Pea was the most popular winter cover crop, but was frequently killed almost completely by diseases. The principal destructive diseases were, in order of importance: black stem, *Ascochyta* sp.; *Septoria* leaf and stem spot; and root rot, *Aphanomyces euteiches* Drechsler. More than 400 varieties and strains of peas were assembled and tested for resistance to these diseases, and to cold injury. No marked resistance to black stem was found; but some resistance to root rot was obtained in selections from a cross between the Austrian Winter pea and a variety known as Nitrogen pea and also between the former and a vigorous non-winter hardy pea from Puerto Rico. Selected strains from these crosses are winter hardy, are somewhat earlier than Austrian Winter and usually produce more green matter. Six of these strains are being tested for seed production in Oregon and for vegetative growth in Georgia; one appears especially promising.

The diseases of other leguminous cover crops and forage crops have been studied: kudzu, cowpea, soybean, *Chamaecrista*, *Crotalaria*, *Lespedeza*, and lupines. At present, the diseases of lupine, including seed deterioration, of the blue lupine are being investigated.

Cooperation in the cotton breeding program and in peanut investigations has been noted in discussing work of the Georgia Experiment Station.

GEORGIA AGRICULTURAL EXPERIMENT STATION

A HISTORICAL SKETCH OF DISEASES OF FOREST TREES IN GEORGIA

Julian H. Miller

A very good early description of the Georgia forest flora is to be found in "Travels of William Bartram". When this trip was made in 1773-78 the Indians still occupied much of the State and most of it was in forests. The longleaf pine was the dominant tree on the coastal plain. In the piedmont, hardwoods, chiefly giant oaks, chestnut, and hickory, predominated. Pines, present in lesser quantity, became abundant in this area only after the original forest was cut down. The mountains also were clothed with hardwoods, principally chestnut, chestnut oak and scarlet oak, with some pine, shortleaf on south slopes, and both white and Virginia pine, at the lower elevations. The Cherokee and Creek Indians cleared very little land, but when the early settlers flocked in after 1800 the picture soon changed. The rapidly formed clearings, reaching a peak about 1850, followed by accelerated soil erosion, presented another environment. On the heels of these major changes we see the rapid progress of certain tree diseases. This could be explained in part on the basis of changes in tree type and in environment, especially in the soil, and of course in large part to introductions of parasitic organisms the traveling American has inadvertently brought in. Some of these major developments in forest pathology are given below.

Phytophthora Root Disease of Chestnut and Chinquapin. Chestnuts and chinquapins were disappearing in this State long before the arrival of the present blight. The first report was probably that of Jones (1) in 1825. The late Chancellor D. C. Barrow of the University of Georgia remembered the many chestnut rail fences in the piedmont section, and that toward the latter part of the last century they vanished in this area along with the chestnut tree. Clinton (3) cited records of chestnuts dying out in the piedmont counties of Hall, Elbert, Carroll and Walton in the 20-year period prior to 1875. However, in 1907 there were still many chestnut trees left on the higher ridges, and mountaineers would come down to Athens in covered wagons loaded with apples and chestnuts. This early dying was probably due to Phytophthora cinnamomi. Proof of the relationship of the fungus with the root disease of chestnut was given by Crandall, Gravatt and Ryan (33). A description was recorded earlier by Crandall (9).

Chestnut Blight (Endothia parasitica). This disease first appeared in the Georgia mountains about 1918, and in 1920 the writer observed many dying trees with characteristic symptoms across Niels Gap in Union County and in Rabun County. A survey was made by Gravatt and Marshall (5) in 1924-25, when the blight was found in most of north Georgia. At that time isolated infection areas existed in Georgia and Tennessee, and the above writers thought the eradication of this spot infection when it was still small would have resulted in delaying the death of trees further north for many years, as the main area was still hundreds of miles north of the Georgia mountains. At the present time most of the large trees are dead, but sprouts are still coming from stumps and partially destroyed trees. These dead trees are fast being taken out for acid wood, and chestnut oak, scarlet oak, and other associated species have largely replaced the chestnut.

Twig Cankers of Asiatic Chestnuts. These cankers caused by the fungus, Cryptodiaporthe castanea, have been reported by Fowler (13) at Albany, Jasper and Savannah.

Freezing Injury to Asiatic Chestnut. Crandall (28) found such injury all over Georgia in November 1940.

Two Leafspots of Black Locust. One of these caused by Macrosporium sp. was reported by the writer (8) from a Civilian Conservation Corps project nursery at Athens in 1935. It was the first reference to the fungus in this country. Davis and Davidson (14) also found it, along with another leafspot (Fusicladium robiniae), in nurseries at Americus and Flowery Branch.

The Popcorn Disease (Sclerotinia carunculoides) of the Mulberry. This disease is confined to south Georgia, where it has long been the custom to have a grove of mulberries in the hog lot. In this respect it is of some economic importance. Jenkins and Siegler (12) report it from Ben Hill, Telfair, Randolph, Peach, Lanier, Berrien, and Jefferson Counties.

Mimosa Wilt (Fusarium perniciosum). While this recently discovered disease was first reported in Tryon, North Carolina, it was soon found in Georgia, and Hepting (17) in 1939 cited it from Monticello and LaGrange. Later Toole (23) showed it to be distributed over most of north Georgia and in one south Georgia county. The writer first noticed it in an escaped mimosa grove along the river in Clarke County in 1938, and these trees all died, even the small seedlings, within two or three years. Since then most of the campus trees at Athens have succumbed, as well as many on the city streets.

Cephalosporium Wilt of Persimmon. This disease of the native persimmon was first noticed in Georgia by the writer in 1940. Several large trees died in the Athens area. It was thought that this tree was doomed, but the disease did not spread very rapidly and now it is difficult to find an infected tree. Beattie and Crandall (16) and Crandall (15) found it chiefly in south Georgia, but did cite a few cases in northwest Georgia.

Glomerella Leafspot of Magnolia. Fowler (37) in 1947 reported a serious spotting of leaves of Magnolia grandiflora over the entire range of the tree. The causal organism is a form of Glomerella cingulata.

A Recently Discovered Elsinoe Spot on Flowering Dogwood. Dr. A. A. Bitancourt first discovered this disease of Cornus florida in Savannah in the spring of 1939. The writer later secured it from street dogwoods in Atlanta in 1947, and since then from many mountain counties near the North Carolina line as well as in Clarke County. It has been described as Elsinoe corni by Jenkins and Bitancourt (38, 39), and they cite the Georgia locations. The fact that it attacks the flowering bracts as well as the leaves and twigs makes it of much more importance than the usual Septoria leafspots. Last spring and summer the writer found it in serious proportions only in the mountains. In Athens it does not seem to be spreading to nearby trees from the first two infected plants. Other dogwoods, such as Cornus amomum and C. stricta, are apparently not susceptible.

Brooming Disease of Various Trees. A witches'-broom of virus origin was found on black locust and reported by Grant and Hartley (10) in 1938. They note that Dr. G. G. Hedgcock discovered it at Ellijay in 1914. Grant, Stout and Readey (26) stated that it was found in Georgia before 1900.

Dr. G. E. Thompson discovered a similar disease on mimosa in Clarke County in 1944.

In 1938 the writer noticed a severe case on Japanese walnuts (Juglans sieboldiana) in Clarke County. These trees were sent here by the U. S. Department of Agriculture, about 25 years ago and planted in three different locations. By 1949 all the trees were affected. Nearby black walnuts and pecans show no such symptoms.

Littleleaf of Pine. This disease probably stands next to the chestnut blight in its far-reaching effect on the forests of the State. It was first discovered and reported for Georgia by Dean D. J. Weddell at Hamilton in a letter to Dr. P. V. Siggers in 1939. It was described by Siggers and Doak (20) in 1940. The next year Toole and Buchanan (22) in a survey reported it from all of piedmont Georgia, chiefly on shortleaf pine (Pinus echinata), but also on loblolly (Pinus taeda). Hepting, Buchanan and Jackson (34) described in detail the symptomology of littleleaf. Campbell (40, 42) in 1948 discovered an association with Phytophthora cinnamomi. At this time littleleaf in Georgia is confined chiefly to the piedmont, the main habitat of shortleaf pine.

A Pine Branch Canker Associated with *Atropellis tingens*. Diller (31) first reported this disease from Georgia in 1943. He studied it on pine plantations in south Georgia. Later he made a State survey and found it widespread on most species of hard pine. One can see this canker commonly on the lower limbs of pines, but it apparently is not a serious factor in the growth or form of the trees.

Brown Spot Needle Blight (*Septoria acicola*) of Pine Seedlings. This is found chiefly on longleaf (Pinus palustris), but occurs on many hard pines, and is well distributed all over south Georgia, and occasionally in north Georgia on some slash pine (Pinus caribaea) plantings. Siggers (32) studied the effect of fires on the disease in Camden County. Hedgcock (7) in 1932 mentioned its occurrence on Pinus palustris, P. taeda and P. virginiana. However, H. W. Ravenel was the first to collect brown spot according to Siggers (32). This was at Aiken, South Carolina in 1876. This locality is near the Georgia line, so it has probably been in this State for many years.

Fusiform Rust (*Cronartium fusiforme*) on Pines in Nurseries. Rust developed as a serious factor in pine nurseries established by the Civilian Conservation Corps during the last decade. Once the main stem of the seedling pine was infected death followed later when the tree was in the plantation. Lamb (19) found a medium amount of infection in south Georgia and light infection in the northern part of the State. This disease is also a serious factor in some plantations, particularly in slash pine. In 1938 the disease was most serious in the nursery and the field. This coming year the disease also promises to be extremely severe.

Pitch Canker, A New Disease of Southern Pines. Hepting discovered this disease in 1945 on Pinus virginiana in North Carolina and later found a similar pitchy canker on the turpentine faces of slash pine in Georgia, and he and Roth (36) published a description. Dr. W. A. Campbell also observed this disease on the former pine in the mountains of north Georgia. The causal fungus was described and named by Hepting (43) as Fusarium lateritium f. pini in 1949.

White Pine Blight. Toole (44) reported a serious blight of white pine (*Pinus strobus*) in three north Georgia counties in 1949. The cause is unknown, but the condition has been observed for years throughout the eastern part of the United States and Canada.

Nursery Blight of Cupressus. The writer noted this blight (*Phomopsis juniperovora*) on *Cupressus sempervirens* growing in a nursery of the Horticulture Department at Athens in 1934.

Blight of Sweet Gum (Liquidambar styraciflua) on the Fort Benning Reservation. Sweet gum trees in the Fort Benning area, both on streets and in woods, have been dying from this blight. It has been described by Garren (45) but he did not determine the cause of the disease. The writer has also studied specimens of drying branches and has not been able to isolate a probable parasitic organism.

Fomes annosus Root Rot of Red Cedar. This disease is common in certain areas of the southeastern piedmont and was observed by Dr. W. A. Campbell on red cedar (*Juniperus virginiana*) in Elbert, Jackson and Morgan Counties in 1949. The fungus has also been found on old stumps of shortleaf, loblolly, and Virginia pine.

In addition to the above important diseases many papers on Georgia tree-inhabiting fungi are to be found in the literature. Ravenel (2) was probably the first to collect fungi here. Specimens from his Darien station were described by either M. J. Berkeley or M. C. Cooke at Kew Botanic Gardens.

Much later there were papers on tree rusts with Georgia locations by Hedgcock (18) and Boyce (30).

Ascomycetes have been listed or described as new by Miller (24, 25), Miller and Burton (27), or Miller and Thompson (21), and the latter (11) has reported some fungi occurring on trees.

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PHYTOPATHOLOGY IN MAINE 1906-1949

Donald Folsom

Since the establishment of the Department of Plant Pathology at the University of Maine at Orono in 1906, most of the phytopathological research in Maine has been done by full-time workers because of the short growing season, the distance of crop areas from the University, and the considerable participation by members of the U. S. Department of Agriculture. Work on potato diseases has predominated because general conditions in Maine have emphasized economic research, and the potato crop has been by far the most important one.

Phytopathologists engaged continuously in research here for fourteen to 35 years each are E. S. Schultz, Donald Folsom, Reiner Bonde, the late W. J. Morse, and M. T. Hilborn. Others who have worked here for shorter periods include I. E. Melhus, L. O. Kunkel, H. A. Edson, C. E. Lewis, M. Shapovalov, G. B. Ramsey, L. O. Gratz, T. T. Ayers, Florence L. Markin, A. E. Rich, A. F. Ross, S. F. Snieszko, and M. R. Harris. Many contributions have been made to phytopathological research by geneticists, entomologists, chemists, and specialists in other sciences.

Close cooperation has been maintained by research phytopathologists with extension specialists and State seed inspection agents, both of whom have furnished new problems and data on old ones, and with visitors making plant-disease surveys. A file is maintained that includes records of all plant diseases found in Maine. With a department library, and a collection of thousands of separates and bulletins catalogued by subject with supplementary author indexes, the Department of Plant Pathology serves as a source of phytopathological information for extension specialists, State agents, teachers, students, and farmers.

POTATO DISEASES

Pioneering research on potato diseases in Maine has been concerned with late-blight epidemiology, blackleg, Rhizoctoniose, potash deficiency, boron toxicity, differentiation of mosaics, insect transmission of viruses, leafroll net necrosis, non-parasitic stem-end browning, Verticillium wilt, spindle tuber, tuber-unit seed plots, foundation seed, Alternaria tuber rot, Botrytis tuber rot, yield reduction by Bordeaux mixture, mahogany browning, new tuber disinfectants and foliage fungicides, and resistance to mosaics, late blight, ring rot, and leafroll. Detailed investigation has been made of the comparative value of fungicides and of the relation of insect infestations to virus epidemics. Techniques have been developed for valuable services such as foundation seed maintenance and Florida winter testing of seed stocks.

FRUIT AND VEGETABLE DISEASES

Pioneering research has been carried on in Maine on apple scab in twigs, storage apple scab, the effect of fungicides on apple trees in replicated plots, winter-hardy apple trees, new apple spray booms, fungicide control of lowbush-blueberry diseases, and resistance to cucumber scab.

CONTROL OF POTATO VIRUS DISEASES

Potato virus diseases in Maine were being studied in 1918 as physiological diseases caused directly by unfavorable climate or nutrition. Before long they were shown to be transmissible by grafting, sap transfer, and insects, and to be spread from one plant, row, or field to another. Differentiation was made between several mosaics, leafroll, spindle tuber, and other virus diseases. Surveys in the early twenties showed that there were no fields in Aroostook County free of mild mosaic in the Green Mountain variety, and that about half the plants of all varieties together were spindle-tuber. All virus diseases reduced the yield rate, and tuber quality was lowered by spindle tuber and, through net necrosis in certain varieties, by leafroll. Symptoms varied with weather and climate, and natural field spread of the viruses differed from one region to another. Soil harboring occurred only in diseased tubers. Healthy seed could be obtained from certain other more northern areas or by developing tuber lines from healthy tubers. Tuber-unit seed plots increased the effectiveness of roguing. Cloth cages kept viruses from entering healthy seed plots. Foundation seed is kept more nearly healthy by planting earlier and in larger seed plots, and by roguing by supervised trained roguers. Selection of the best stocks is made possible by a large-scale mid-winter Florida test run on 1600 800-tuber samples whose dormant period has been shortened by chemical treatment. Virus X (latent mosaic) is reduced by tuber

selection based on greenhouse tests on indicator plants. Aphid control with insecticides, though disappointing in virus control, has led to increased yields. New varieties have been introduced that are resistant to mild mosaic.

UNIVERSITY OF MAINE

PLANT DISEASE INVESTIGATIONS
AT THE NEW YORK STATE AGRICULTURAL EXPERIMENT STATION,
CORNELL UNIVERSITY, GENEVA, NEW YORK

Otto A. Reinking

The plant disease investigations conducted at the New York State Agricultural Experiment Station at Geneva, New York, are primarily concerned with diseases affecting orchard fruits, nursery fruit stocks, small fruits, grapes and vegetable canning crops. In order to avoid undue duplication between the investigations conducted at Geneva and the Cornell Agricultural Experiment Station at Ithaca, projects under each general group of investigation are apportioned so that each station conducts those projects for which it is best suited. In orchard fruits, disease control studies are done at Geneva. A division of the virus troubles is made whereby the main determinations and host relationships are conducted at Ithaca and special studies on control are receiving attention at the Geneva Station. Cooperative projects on many phases of investigations are carried on by both institutions. Practically all small fruit and grape disease investigations are handled at Geneva. The vegetable studies at Geneva are primarily confined to the canning crops, such as peas, beans, tomatoes, beets, carrots and cabbage. Investigations on potatoes, grain crops, ornamentals, forest trees and many of the market garden and muck-grown vegetables, such as onions, lettuce and celery, are conducted at the Ithaca Station. Results of investigations conducted at Geneva are made available to the growers primarily through the extension service of Cornell University.

Progress in disease control has led to a practice of better and more economical control of our major plant diseases. The main projects deal with fungicides and their application, and the production of resistant varieties. The Geneva Station has helped in the gradual development that has led to a more practical and efficient control of many of the diseases of fruits and vegetables in its sphere of investigations.

A spray program with new fungicides takes years of development before it is safe to place into practice. Already the premature general use of certain organic sprays appears to have resulted in the reduction of fruit crops the following year. We must know what effect the new fungicides have on the trees or vegetable crops as well as on the control of a fungus before we can recommend a change. In our plant pathological investigations we are not only interested in fungicides that control disease but in those which control with the least amount of injury to the plant under consideration. The ideal fungicide is one that will control disease and at the same time increase the productivity of the plant. With the interest shown in commercial development of the many organic fungicides, attainment of this goal appears to be possible.

A review of some of the outstanding accomplishments made at the Geneva Station is presented on the following pages indicating the part the station played in the evolution of certain control practices. Short statements of the work in progress are included. Examples herein presented of progress made in the past on economic control along with the forward-looking program to still further improve on these, gives an indication of the general objectives of the program of plant disease control. These studies are being conducted with Drs. J. M. Hamilton and D. H. Palmiter on orchard fruit, Dr. A. J. Braun on small fruit, Dr. H. C. Young, Jr. on fruit nursery stock, and Drs. W. T. Schroeder, R. E. Foster and O. A. Reinking on vegetable disease control investigations.

ORCHARD FRUITS

Apple scab control is the main orchard fruit project. Our major endeavor is to obtain fungicides which will reduce the number of sprays necessary to obtain economical control, and to develop spray programs which through proper timing and the use of newer types of spray machinery will reduce the cost of spraying. The results of work started in 1930 have brought about the change from lime-sulfur to wettable sulfurs. Wettable sulfur is now the accepted basic fungicide. Those materials in the carbamate and the phenyl mercury groups appear to show most promise in the fungicide work of recent years. Data indicate that they may be used for certain applications in the spray program to reduce the number of sprays required for control of rust (*Gymnosporangium* spp.) and scab (*Venturia inaequalis*) respectively.

Field investigations have shown that some of the organic compounds cause various types of injuries to the tree, which appear to be cumulative. In some cases it even appeared that the chemicals used stopped fruit bud formation with a resultant reduction of flowering and fruiting the following year. Because of this fact, a five-year orchard spray test in which micronized

wettable sulfurs are compared with the most promising organic materials has been started. The object is to determine the possible cumulative effects of the various compounds on total fruit yield, quality, and tree growth. This forward looking program should produce results that will avoid many pitfalls in the recommendation of a new spray program.

Resistance studies on apple scab control are conducted in cooperation with the U. S. Department of Agriculture and several State experiment stations in regional tests.

Eradicant treatments for the control of apple scab in the Hudson Valley area have been shown to be economical when scab carryover is heavy. Elgetol or ammonium sulfate, plus a penetrating agent, applied to old leaves on the ground before the trees reached green tip stage were the most effective treatments. (Geneva Bulletin 714).

Cherry leaf spot (Cocomyces) investigations have resulted in a change from sulfurs to insoluble coppers. Now, under special conditions the coppers may be replaced or enhanced by the use of organics such as iron carbamates.

New means of applying fungicides as spray dusts or concentrate sprays and development of formulations for use with these newer types of applicators are being investigated. The development of satisfactory machines for the application of spray dusts and concentrate sprays holds promise for a reduction in cost of application as well as decreased spray injury.

Urea foliage sprays as a means for controlling nutrition of fruit plants and their disease relation was a development started at the Geneva Station. Application of nitrogen to the foliage of trees in combination with spray materials opened a new field in the development of quality fruit production and new ideas in control of certain diseases. There are indications that application of nitrogen to the soil apparently results in more scab than when applied to the foliage. The application of nitrogen to the foliage of the apple and pear trees at certain stages of growth may be one method of reducing ravages of the pear blight organism. Long-time tests are underway to prove these points.

Apple rust diseases are now readily controlled by the application of iron carbamates. These studies were initiated a number of years ago in the Hudson Valley and have solved the spray program for control. The ferric carbamates are specific and phenomenal in their control of rust and need not be timed so closely as was the case with sulfur sprays.

Peach leaf curl (Taphrina deformans) investigations have resulted in the development of a more flexible and economical spray program. Dinitro materials have been found to be eradicants much in the same order of lime-sulfur. They not only give excellent leaf curl control but expedite spraying when the peaches are interplanted with apples.

Brown rot of stone fruits (Monilinia) still needs much more study. Investigations indicate that the sulfur sprays will not control under all conditions. Organic fungicides are being tested. The nutritional angle in relation to susceptibility, insect control, and the proper handling of fruit at harvest time are other important phases being studied.

Investigations on increasing the resistance of the plant to fungous, bacterial, and virus infection by absorption of the toxicant into the host tissues as yet have not given uniformly good results.

Sooty blotch (Gloeodes) of pears has been satisfactorily controlled in the Hudson Valley with one application of a dinitro material like Elgetol. The same treatment has given satisfactory control of pear psylla. One spray at a higher concentration is now being applied to control both troubles. Further studies on the control of Fabraea leaf and fruit spot are being made. The ferric carbamates show promise.

Fire blight (Erwinia amylovora) control through spraying with germicidal, nutritional and hormone-like sprays are underway. Resistant variety tests are being made in cooperation with various State and U. S. Department of Agriculture regional projects.

X-disease of peach (virus) has been satisfactorily controlled by removal of diseased chokecherries (Geneva Bulletin 704). These studies were made primarily in the Hudson Valley. Further cooperative studies have shown that the same disease is present on sour and sweet cherries. No vector has been found although studies along these lines have been enlarged. Apparently the disease is only spread from the chokecherry to the stone fruits mentioned and does not spread from tree to tree within the peach or cherry orchards. Work on the entire X-disease complex is being continued.

NURSERY FRUIT STOCKS

The development of a spray program for control of apple scab, cherry, plum, quince, and pear leaf spots, and powdery mildew on all stock is of first importance. The project is being carried out in cooperation with the Division of Entomology at Geneva in order to formulate com-

bination sprays for insect and disease control. While many of the fungicides used for mature trees may serve for certain diseases, this is not true for the control of all the troubles encountered in the nursery. The timing of both fungicide and insecticide sprays for economic control needs further study.

The cause and control of storage molds and cankers is another project conducted in cooperation with the Division of Pomology at Geneva and with certain nursery companies.

A project relative to the influence of the rootstock on the scion susceptibility to scab in apples is now receiving attention. It has been started with the cooperation of the Division of Pomology, Geneva.

A long time project on the production and maintenance of virus-free foundation stock of commercial fruit varieties for the nursery trade was inaugurated in cooperation with the Division of Pomology, Geneva, and the Department of Plant Pathology, Ithaca. It is at present confined to stone fruits, principally sour cherry, but will be gradually enlarged. A program of indexing of sour cherries and seedling root stock for freedom from virus infection was started using the present accepted methods of indexing. Further studies on the improvement of methods of detection are underway. The present method used has been adequate in pointing out sour cherry trees infected with ringspot and yellows. Whether the method presently in use is 100 percent efficient remains to be seen. Virus indexing is done both in the greenhouse and the field. An isolated block is maintained for the production of healthy budwood, the parent trees having been indexed at least twice. Blocks of diseased trees are maintained for further study of the virus troubles and for a source of the different virus diseases for use in special studies.

At present there are 16 Montmorency sour cherry trees in the isolation block which have been indexed six times without showing any evidence of virus. Buds from these trees are being used for propagation on rootstocks which are as free from virus diseases as can be obtained at present. Budwood from these 16 trees, in limited quantities, was made available to the nursery industry in the 1949 season. There are also 15 English Morello trees in the isolation block which have been indexed twice, and other varieties of both sweet and sour cherry will be added to the program.

SMALL FRUITS AND GRAPES

A revision of the spray schedules for the control of grape diseases has been a gradual, evolving process during the past nine years. The first schedules included the use of bordeaux mixture and insoluble coppers for the control of the three major diseases, i. e., black rot (*Guignardia*) and downy and powdery mildews (*Plasmopara viticola*, *Uncinula necator*). An injury complex due to copper sprays soon became apparent. Investigations made from 1941 to 1944, as reported on in Geneva Bulletin 712, resulted in new schedules, using reduced amounts of copper and a reduction in the number of spray applications. A reduction of from 50 to 75 percent was made in the amount of copper sulfate required to spray an acre of grapes. Through proper timing of the applications, a 40 percent saving in labor resulted from the decrease in the number of applications necessary for control. It was found that spray injury caused by the insoluble coppers could be reduced by the addition of 1 pound of lime for each 1 4 pound of actual copper in the spray mixtures. The grape spray program, however, was not considered completely satisfactory. Although the insoluble coppers with lime were shown to be less injurious to the plants, their effectiveness in controlling disease under epidemic conditions was not certain.

Tests conducted during the past five years have shown that ferric carbamate used as a spray at 1 or 2 pounds to 100 gallons of water controlled black rot better than bordeaux mixture at concentrations of 4-4-100 or 8-8-100. This material appears to cause little or no injury. In fact ferric carbamate apparently stimulates vine growth and yields of grapes, especially under certain conditions of nutrition. It was found also that early applications of this material reduced the injury from later applications of bordeaux mixture. No satisfactory substitute for copper has been found yet for the control of downy and powdery mildews.

Studies with new types of machines for applying dusts, wet-dusts, and concentrate sprays to grapes indicate that these applicators may become more satisfactory than the conventional sprayers. The use of air-blast methods makes possible more rapid applications using less fungicide per acre, resulting in lower cost per application. Furthermore, copper fungicides applied as concentrates appear to be less injurious to the vines. Progress is being made in the development of formulations of fungicides for use with these newer machines.

A revised spray program for the control of anthracnose (*Elsinoë veneta*) of raspberries has progressed to a point where these studies may be terminated. It has been shown that anthracnose can be economically controlled by the use of proper cultural practices along with one application

of lime-sulfur, 8 gallons liquid lime-sulfur added to 92 gallons of water. It was found that this spray is most effective if applied just as the second or third leaf is expanding from most of the buds on the fruiting canes. At this time the fungus is no longer dormant and is more susceptible to the toxic effect of the spray.

A control for spur blight of red raspberries was published during 1945 in Geneva Bulletin 711. Studies have been terminated.

The virus diseases of raspberry have been satisfactorily controlled by following the Geneva Station recommendations made in bulletins published in 1937. The methods demonstrated to be effective include planting of certified disease-free stock, plus eradication of diseased wild brambles in the vicinity of commercial plantings and roguing as disease appears in new plantings. Studies on the production of disease-resistant varieties are underway in cooperation with the Division of Pomology, Geneva.

The appearance of red-stele (*Phytophthora fragariae*) in strawberries in a number of commercial plantings has made it imperative to conduct more studies on this disease. Resistance studies are receiving attention with the cooperation of the Division of Pomology, Geneva.

Virus diseases, especially strawberry yellows, are becoming more acute. By indexing and isolation a stock of virus-free clones of certain of the commercially important varieties of strawberries are being obtained. Resistance studies are underway in cooperation with the Division of Pomology, Geneva.

Currant cane blight (*Botryosphaeria*) and Botrytis fruit rot control is receiving attention in the Hudson Valley. Both troubles are dependent upon weather conditions. Field tests on sanitation and spraying are the main avenues of attack. Special fungus studies in the laboratory and greenhouse are included. Studies on currant leaf spot control were published in 1945 in Geneva Bulletin 709.

Stunt, mummy berry, and stem canker of blueberry are under study. The nutritional phases are conducted in cooperation with the Division of Pomology, Geneva.

CANNING VEGETABLE DISEASES

The nature and control of root rots of peas is an example of a long time, extremely complex, problem. Much of value already has been learned but years of study are still needed with a well-planned, long-time rotation field experiment to give us more complete information. Investigations on the causal organisms during the seasons from 1936 through 1941 established the important root-rot organisms, their distribution, relation to some environmental factors such as seasonal variations in disease appearance and destruction, and preliminary effects of rotations and fertilization. The results were published in Geneva Technical Bulletin 264. The studies showed that *Fusarium solani* v. *martii* f. 2 and *Aphanomyces euteiches* were the most active organisms. The severity of each is dependent upon seasonal growing conditions. The organisms and disease were found in a wide range of soils with reactions ranging from pH 5.4 to pH 7.5. It was found that *Aphanomyces euteiches* may be of relatively little importance during an extremely dry season even though the soil is infested. During periods favorable to the development of this organism, especially in the early stages of growth of peas, 100 percent destruction may take place, thereby destroying the crop before it even gets underway. Early planting in well-rotated soils to bring the first growth on when the soil temperature is below an optimum for fungus growth, especially of *Aphanomyces*, avoids a large part of the destructive action on young, tender plants. The *Fusarium* is more destructive later in the season during hotter, drier weather. The effect of this organism on the host is especially marked if hot, dry weather prevails during the last two weeks of pea growth. A six-year study of fields in the Geneva Station showed that the important root-rot organisms were not entirely eliminated by a three-, four- or five-year rotation. Investigations have shown that commercially profitable yields can be obtained on properly rotated and fertilized fields with early plantings.

Apparently, the virulent pea root rot *Fusarium* is capable of living over on beans, and possibly this characteristic serves as a means of maintaining the pathogen in an active state and capable of infecting a susceptible host following in rotation. Whether or not other plants than beans could function in this manner was not ascertained.

The above studies were amplified with a rotation plot started in 1940 to determine the effects of a fallow, legume, and non-legume rotation in comparison with continuous peas. In 1941 and 1942, disease caused a severe reduction in yield in the plots planted with continuous peas. A total loss occurred in 1943, 1944, and 1945 in the continuous pea plots. The organisms had built up on the soil to a point where it was impossible to grow peas during those years favorable for fungous development. *Aphanomyces* was the predominant destructive fungus, particularly

during the early part of the season, while Fusarium developed later. The severity of root rot in the other rotations during these years varied from moderate to severe with yields of from 1100 to 3300 lbs. shelled peas per acre. A summary of the yield data in 1945 showed a significant difference in yields between rotations, with the legume rotation producing greater yields than the non-legume which was equal to the fallow, and the fallow, in turn, being higher than the continuous peas. Commercial fertilizer at the rate of 600 pounds to the acre significantly increased the yield in all rotations.

In 1946, the last year of this particular rotation test, the continuous pea plots that showed failures due primarily to Aphanomyces root rot in all years since 1940 produced yields varying from 1500 to 3500 pounds of shelled peas to the acre. These were, except in one instance, almost as high as those in the other rotation plots that had yields varying from 2800 to 4000 pounds to the acre. All rotation plots with 600 pounds of a commercial fertilizer gave best yields. These data showed that root-rot infested soil can produce an excellent crop of peas, in spite of the presence of the organisms in the soil, when environmental conditions are favorable to the crop and unfavorable to the disease organisms.

To minimize variation due to seasonal conditions, which was shown to be an important factor in the development of pea root rot, a new rotation experiment was designed in cooperation with the Division of Vegetable Crops, Geneva, to study the effects of seven different vegetable canning-crop rotations on the incidence of root rot, quality and yield of peas, and on the fertility level and structure of the soil. Each rotation is for five years and five separate fields are set up so that each crop in each rotation occurs every year, thus minimizing variation due to seasonal conditions. Here again, we have another example of a carefully laid-out, long-time test which should solve further many perplexing problems connected with pea root rot.

In addition to the rotation tests on pea root-rot control, tests are underway in cooperation with the Vegetable Crops Division, Geneva, on fertilizer carriers and amendments in relation to pea root rot. Some of the various soil amendments tried in the past several years indicate that a number of materials, including gypsum and anhydrous ammonia, show promise in reducing losses.

A field study of the relation of soil type, drainage, fertilizer level, and cropping systems to the incidence of pea diseases and the effects of these various factors on the yield and quality of peas is being conducted in cooperation with the Division of Vegetable Crops, Geneva, and the Department of Agronomy, Ithaca. In these studies, an attempt is being made to correlate yield data with growing conditions found in a survey of various pea fields located in the pea-growing regions of western New York.

The development of pea varieties tolerant to heat and disease is receiving attention in cooperation with the Division of Vegetable Crops, Geneva. Results thus far from a disease standpoint have not been consistent under field conditions, owing to variable year to year environmental conditions and to the non-uniform infestation of the causal organisms. Greenhouse tests, using pure cultures of the specific pathogens in sterilized sand under controlled conditions, indicate that this technique might prove a valuable aid in a search for resistance.

A revised program for the control of diseases of tomato seedlings in the greenhouse has progressed to a point where these studies may be presented in a bulletin.

The use of growth-regulating and other materials to prevent the development of tomato ripe fruit crack molds and to hasten the rate of ripening of late-set tomato fruit by defoliation or otherwise killing the vines has been receiving attention. Indications are that the killing of the vines may reduce yield if defoliation materials are applied too early. Unless adequate disease protectant measures are adopted, it appears that any advantage gained by the use of defoliant may be offset by increased development of anthracnose. Further studies are underway.

The development of an economic spray program for the control of tomato leaf blights and fruit rots has passed through various experimental phases during the past 15 years. An excellent economic control for use under New York State conditions is now on hand. Investigations conducted in 1937 indicated that bordeaux mixture at a concentration of 4-4-50 was injurious to plants and that apparently the injury was due more to the lime than to copper. Tomatoes belong to a group of lime-sensitive plants. These findings resulted in the trial and use of red copper oxide followed by trials with various other "insoluble coppers." It was shown that particle size and the method of manufacture are closely correlated with the effectiveness of cuprous oxide. Further studies resulted in the production of yellow cuprous oxide which had a smaller particle size and proved to be a better fungicide but was more toxic to plant tissues. Since some of the fixed copper compounds gave good control without causing pronounced injury they were recommended for tomato sprays. The next step in the development of the program was the use of insoluble coppers in the first two sprays, when the plants were younger and in blossom, to

avoid lime injury and reduction of blossoms, followed by a 4-2-50 bordeaux. In 1941, gross returns from control amounted to from \$13 to \$54 an acre. During 1942 and 1943 the Phytophthora late blight disease, for the first time in recent years, became destructive in tomato fields. Anthracnose caused by Colletotrichum was gradually becoming more widespread. The advent of these two diseases showed that bordeaux mixture and the insoluble coppers did not produce as effective control as we desired. The copper materials were not effective in controlling anthracnose. Preliminary studies indicated that some of the new organic fungicides, especially the ferric and zinc carbamates, apparently controlled anthracnose better than copper sprays. During 1944 to 1946, further tests with a number of organic and copper fungicides were made. Early blight (Alternaria), late blight (Phytophthora), leaf mold (Cladosporium) and anthracnose (Colletotrichum) were all present in a severe form. It was found that no single fungicide tested gave maximal control of all four diseases. The fixed coppers gave good control of leaf mold, early blight and late blight, were slightly inferior to bordeaux 4-2-50 for the control of late blight. No copper fungicide tested gave adequate control of anthracnose and all were injurious, some more so than others, when used in the early applications. Many organic fungicides were tested. Best control of the four diseases was obtained with an alternate schedule of Fermate or Zerlate and various copper fungicides. No apparent injury resulted from these schedules, probably because of the fact that bordeaux was applied after August 1, after which time defloration, the principal injury factor, is not reflected in yield except during an unusually prolonged harvest season. These investigations resulted in the Zerlate-bordeaux schedule (Zerlate-Zerlate-Bordeaux-Zerlate-Bordeaux) which was found to be the most effective and efficient schedule for the control of the major diseases of tomatoes, i. e., early blight, late blight, and anthracnose. No other fungicide tested, either alone or in an alternate schedule, gave such good control. The results of these investigations were published in Bulletin No. 724 of the Geneva Station.

A comparison with airplane dust applicators and helicopters and dust applicators with ground sprays in tomato disease control indicated the latter to be more effective. Further studies, possibly with special concentrate spray equipment on aircraft, are indicated.

Investigations on the relative value of various adhesives in tomato spraying, using a newly developed print method to determine the deposition, distribution, and weathering of the fungicide pattern, indicate further benefits in a spray program. Studies are being continued.

Two years' data indicate rather definite and inherent responses of tomato varieties to the diseases late blight and early blight. It is apparent that different responses to spraying are obtained with some varieties. Apparently some varieties are more toxic to sprays than others. Further studies are underway.

The use of oil wax emulsions as sprays for the control of tomato blossom-end rot is worthy of further study. On the basis of the 1948 data increases in yield of marketable fruit were obtained which justified the added expense.

The development at the Geneva Station of a leaf print method to determine the deposition, distribution, and weathering of the fungicide pattern made it possible to determine the exact distribution of various sprays. This method was perfected by the Division of Food Science and Technology in cooperation with the Division of Plant Pathology, Geneva, for copper and Zerlate sprays or dusts and is used extensively in the tomato studies. The deposition and distribution of copper or Zerlate fungicides on the upper and lower surface of each leaf can be determined by placing the leaf between two sheets of paper impregnated with a chemical which reacted with the copper or Zerlate compounds and thereby made an imprint on the paper. The use of this method for the determination of the efficiency of operation of various spray and dust equipment has been found to be very useful and practical. Studies on the perfection of this method to include other fungicides are underway.

A project on the epidemiology and control of tomato anthracnose is receiving major attention. Far too little is known about the distribution and habits of the fungus, Colletotrichum phomoides, causing the disease. In addition to a study of the life cycle, studies include susceptibility tests on tomatoes of related species of Colletotrichum rot-producing-fungi found on other crops, tomato variety susceptibility tests, and field work involving fungicides and tomato varieties in relation to possible different reactions on tomatoes by strains of the fungus.

Breeding tomatoes for control of leaf blights, Verticillium wilt, and fruit rots is gradually assuming more importance in our vegetable disease control program. These investigations are being enlarged upon in cooperation with the Division of Vegetable Crops, Geneva.

During the past 10 to 15 years the Division of Plant Pathology, Geneva, has been one of the leaders in the development of seed treatment of canning crop vegetables. As a matter of fact the initial investigations and practical applications on vegetables were started at the Geneva Station

with the treatment of pea seeds with red copper oxide. These investigations initiated a new field of treatment for vegetable seeds to control seed decay. The program has progressed from the use of metallic fungicides to include the large field of organic fungicides. Acceptance of pea seed treatment was at first slow. In 1934 red copper was used by about 60 pea growers. In 1935 several thousand bushels of seed were treated. With the finding that graphite-treated seed along with the red copper oxide reduced friction in the seed drills to normal, the use of the fungicide in 1936 increased to 50,000 bushels of seed or enough to plant more than 10,000 acres. From then on pea seed treatment by this method was more and more extensively used, not only in New York State but in other pea-growing States. In 1936 in New York State the average increase in stand due to treatment of Surprise peas was 22 percent. Studies on its use for other varieties were underway in order to determine possible injury to susceptible varieties of peas. By 1938 some 110,000 bushels of peas were treated in the State. Studies indicated that injury resulted when fertilizer was sown with treated seed, and on acid soils. Certain drawbacks and possible injury to certain varieties of peas developed with red copper oxide, indicating the need for further study. These investigations led to the development and use of Spergon by the Geneva Station. The product was found to be superior to red copper oxide on peas. Spergon was shown to be non-toxic to practically all pea varieties, needed no lubricant and showed increased yields even on the Alaska peas which did not respond so well with the copper treatments. By 1942 from 80 to 90 percent of the commercial acreage in New York was treated with this recently introduced seed protectant. Its use in other States was large.

The promising investigations on the control of pea seed decay, started at the Geneva Station, opened up the entire field of vegetable seed treatment. Studies at the station were enlarged upon to include the treatment of all seeds of vegetable canning crops. Tests with available new organic compounds were initiated and results of this work showed that certain vegetables responded better to particular fungicides. Studies on sweet corn, spinach, beets, carrots, and cucurbit seeds were made. The original investigations at the Geneva Station led to nation-wide cooperative tests, which resulted in unified fungicidal vegetable seed treatment recommendations. A summary of vegetable seed treatment will be presented in a bulletin now in the process of preparation.

Cabbage yellows (*Fusarium oxysporum* f. *conglutinans*) investigations started in 1937 had as their first object the testing of resistant varieties under New York conditions and to acquaint the cabbage growers in the State with the seriousness of the problem and its control. Three years' results of replicated and commercial field tests with cabbage yellows-resistant varieties of early, mid-season and late types were published in 1940 in Station Bulletin 689. This work and other publications made the growers more conscious of the trouble and brought them up to date with the latest control development. These studies indicated that resistant varieties then on the market were not entirely adequate to produce the yields and types required by the New York State cabbage growers. Need was shown for an earlier resistant kraut and market type and for resistant Danish types. Breeding for the production of such types was started and is now in progress. A number of promising strains of resistant Danish and kraut types are being developed for release.

An internal discoloration of cabbage, possibly a nutritional trouble, is receiving attention in cooperation with the Division of Vegetable Crops.

A perplexing beet root rot trouble is receiving added study. Apparently this trouble is becoming more widespread and appears to be developing into a major problem.

Carrot yellows caused by the aster yellows virus has increased in the past few years in western New York and threatens the production. Infection in fields varied from 5 to 78 percent. Investigations have been underway since 1944 in cooperation with the Division of Entomology at Geneva. Life history studies with the six-spotted leafhopper (*Macrostelus divisus*) indicated that control could be affected through a control of the insect. Data accumulated over the past three years on the use of DDT for yellows control showed an effective and practical method of control. These studies terminated in the publication of Geneva Bulletin 737. Further investigations are underway on methods of application with different types of sprayers.

Susceptibility studies with carrot yellows have been underway and some differences in response have been noted under field conditions. Whether this is due to leafhopper preference rather than to an inherent physiological resistance to the disease needs further study. These studies indicate that further selection for increased tolerance or resistance are warranted.

The control of insects and diseases of cucumbers and melons is receiving attention in cooperation with the Division of Entomology. These studies are primarily concerned with control of bacterial wilt and virus troubles through control of insect vectors.

Hop disease investigations have developed an adequate spray program for the control of the major diseases. Emphasis is now placed on the development of disease resistance in hops by

breeding in cooperation with the Division of Pomology at Geneva. Variety resistance tests as well as selections for resistance have produced some promising material for further studies.

NEW YORK STATE AGRICULTURAL EXPERIMENT STATION, GENEVA

PLANT PATHOLOGY AT WEST VIRGINIA UNIVERSITY: PAST AND PRESENT x

PAST

C. R. Orton

The history of a department is a record of events during the life of the department, which have influenced its development. It should include personnel, its activities, administration, cooperation, finances and effects on the general welfare.

The first publication from West Virginia University dealing with plant pathology was a brief description of some common diseases in Bulletin No. 21, April 1892, by A. D. Hopkins and C. F. Millspaugh under the title, "Injurious Insects and Plant Diseases."

The earliest experimental work in the field of plant pathology at West Virginia University was conducted by F. W. Rane, Horticulturist in the Agricultural Experiment Station, on the control of early blight of the potato and potato scab. It was found that three applications of Bordeaux Mixture controlled early blight on all but the most susceptible varieties, and that barnyard manure and lime applied to the soil increased scab, while soaking the seed tubers in corrosive sublimate reduced scab. (Bulletin 38, Nov. 1894).

The systematic study of plant diseases at this Station may be said to have been initiated by J. L. Sheldon, who was Plant Pathologist and later Bacteriologist for the Station during the years 1903 to 1907. As plant pathologist in 1903, he was perhaps the first person to hold that title in the United States. Sheldon found that the anthracnose of watermelons was a serious disease in the Ohio Valley and by means of controlled experiments showed that the fungus from watermelon would infect cucumber, gourd and muskmelon, but neither squash nor pumpkin, nor wax beans. Spraying experiments with Soda-Bordeaux, Bordeaux, and ammoniacal copper carbonate, showed a decided decrease of the disease on blocks sprayed with the two Bordeaux mixtures, while plants sprayed with ammoniacal copper carbonate were not much better than the unsprayed plots. (Sheldon, J. L., Muskmelon Blight. West Virginia Agr. Exp. Sta. Circ. 2. 1903; *ibid.* Bull. 94, Dec. 1904, Diseases of Melons and Cucumbers, West Virginia Agr. Exp. Sta.).

Sheldon studied the ripe rot of guava, an important disease caused by *Glomerella psidii*, the perfect stage of which he discovered and fully described. (Bull. 104, Apr. 1906).

During Dr. Sheldon's tenure a systematic attempt was made to collect and incorporate in a herbarium the parasitic fungi of the State. The collections were all studied carefully and accurately labeled. They form the basis of the known plant diseases of West Virginia. He published three accounts of his collections ("Report on Plant Diseases of the State. West Virginia Agr. Exp. Sta. Rept. 1903-04. 67-93. 1904; A Report on Plant Diseases of the State. West Virginia Agr. Exp. Sta. Bull. 96. Jan. 1905; The Principal Plant Diseases in 1906. West Virginia Agr. Exp. Sta. Rept. 1905-06: 29-39, 1906).

Dr. Sheldon's last publication as a member of the Agricultural Experiment Station Staff appeared as Bulletin 105, June 1906, under the title "Tubercles on legumes with and without cultures." He was assisted in 1907 by Carl Hartley, a young graduate from the University of Nebraska. The following quotation from Dr. Hartley in a letter dated August 10, 1949, is interesting: "Charles E. Bessey sent me to West Virginia for my first job because of his high opinion of Sheldon as a teacher, which I can emphatically confirm."

Sheldon resigned from the Agricultural Experiment Station on June 30, 1907, when he was appointed Professor of Botany and Bacteriology in the College of Arts and Sciences. From that time until 1917, plant pathology and bacteriology were taught by Dr. Sheldon. He offered two courses, one an elementary course offered in the spring term; the other an advanced course offered throughout the year by special arrangement. Sheldon also taught, in addition to botany, three courses in bacteriology--general, agricultural and medical. In 1917 N. J. Giddings became a member of the Agricultural College faculty and offered his first course in plant pathology.

In the fall of 1908, N. J. Giddings, a graduate of the University of Vermont with a Master's degree, and, at that time, employed as Assistant Botanist of the Vermont Agricultural Experiment Station, was engaged as bacteriologist and assumed his duties at the West Virginia Agricultural Experiment Station on February 22, 1909. He was given quarters in the Northeast corner of the first floor of the old Experiment Station building. The facilities were restricted to a few test tubes, a Spencer microscope, herbarium, transfer room, and an old roll-top desk and chair.

This was a great transition from a well-equipped laboratory at Vermont, but Giddings attacked the problem with ability and enthusiasm and within a few years he secured equipment that surpassed that in the laboratories of many larger institutions.

The first assignment handed Giddings was the preparation of a station bulletin on "Diseases of Garden Crops and Their Control" which was published as Bulletin 123, May 1909. Regarding this, Giddings made the following comments: "Soon after it was published, F. C. Stewart of the Geneva, New York Station wrote me expressing his opinion of young upstarts who wrote bulletins without any real knowledge of the problems existing in the area where he was located. Stewart was right and I wrote him to that effect, although the criticism did not make me any happier." To offset this discouragement he received a very kind and encouraging letter from Professor Charles Bessey, which was deeply appreciated.

As Giddings was employed as bacteriologist, his early research in the West Virginia Agricultural Experiment Station was in that field. He was assigned projects in cooperation with other members of the staff. The first was a study of the bacteria in milk, the results of which were published under the title "Experiments in the Production of Sanitary Milk" (Atwood, Horace, and N. J. Giddings. West Virginia Agr. Exp. Sta. Bull. 134, 1911.) The second was upon the effects of high pressure on microorganisms in cooperation with B. H. Hite. This was pioneer research which resulted in the establishment of general principles upon which much of our present knowledge regarding the sterilization of food products is based. The work was published under the title, "The Effect of Pressure on Certain Microorganisms Encountered in the Preservation of Fruits and Vegetables" (B. H. Hite, N. J. Giddings and Charles E. Weakley, Jr., West Virginia Agr. Exp. Sta. Bull. 146, 1914). This work led later to the first proof that a virus could be inactivated by high pressures. In collaboration with Allard of the U. S. Department of Agriculture and with Hite, it was proved that tobacco mosaic was inactivated by pressure of 130,000 pounds and above (Giddings, N. J., H. A. Allard, and B. H. Hite, "Inactivation of the Tobacco Mosaic Virus by High Pressure." *Phytopathology* 9: 1919).

Giddings carried over from his Vermont experience an interest in potato blights. It is not surprising, therefore, to find that he started potato spraying in 1909 which continued for several years. His first tests were at Morgantown, followed by plots at Reedsville and Moundsville. ("Potato Spraying in 1909 and 1910. West Virginia Agr. Exp. Sta. Rept. 1909-1910: 18-22, 1910; Potato Spraying Experiments in 1911. West Virginia Agr. Exp. Sta. Rept. 1911-12: 77-78. 1912). During these experiments, he developed a three-row boom with two nozzles at each row, illustrated in the 1909-10 report, p. 21.

In the fall of 1911, C. M. Gifford, a Vermont graduate, was appointed as assistant bacteriologist in the Station but, most unfortunately, he was drowned at Christmas time while skating on the Monongahela River.

In the fall of 1911, D. C. Neal, a graduate of Mississippi College of Agriculture and Mechanic Arts, was appointed Assistant Plant Pathologist. He assisted Giddings with the spray program for the control of apple rust and other apple diseases. He resigned March 1, 1914.

An important event occurred in 1912 when plant pathology was first recognized as a department in the Agricultural Experiment Station, and Giddings' title was changed from bacteriologist to plant pathologist (W. Va. Agr. Exp. Sta. Rept. 1911-12: 54. 1912).

The year 1912 was a fruitful one for the Department. It may be called the period of national recognition. Giddings published his first two papers in *Phytopathology* that year--the first on "A Practical and Reliable Apparatus for Culture Work at Low Temperatures" (*Phytopath.* 2: 106-190. 1912). This apparatus consisted of a standard incubator superimposed upon an ice-box and equipped with thermo-regulator, small electric motor, rotary pump, and suitable copper piping. It worked. The second was a short paper by Giddings and Neal on "Control of Apple Rust by Spraying" in which they demonstrated that apple rust can be controlled with Bordeaux Mixture by the accurate timing of frequent applications at the critical periods of sporidial discharge (*Phytopath.* 2: 258. 1912.)

About the same time, the Department of Horticulture moved from the old Experiment Station Building into a temporary building (Oglebay Annex) and Plant Pathology was permitted to expand across the halls and to use the hallway to house the herbarium cabinets.

Additional funds were made available for the employment of another staff member, and Anthony Berg, a recent graduate from the University of Wisconsin, was appointed Assistant Plant Pathologist, March 15, 1913. Giddings and Berg made an excellent team and established plant pathological work at the West Virginia Agricultural Experiment Station on a sound basis, through their studies on apple rust. This problem had been of prime importance for many years in the Shenandoah Valley. It was estimated that rust caused a loss of \$75,000 in one county in 1912. Work was begun on apple rust in 1910, but a formal project on apple rust was not initiated until 1913. It was continued until after Giddings resigned in 1929. Several noteworthy contributions to our knowledge of this disease were made during that period viz - "Apple Rust" by Giddings and Berg (West Virginia Agr. Exp. Sta. Bull. 154. 1915); "New or Noteworthy Facts Concerning Apple Rust" by Giddings and Berg (*Phytopath.* 6: 79. 1916); and "Infection and Immunity in

Apple Rust" by Giddings (West Virginia Agr. Expt. Sta. Bull. 170, 1918), a classic study of this disease. It was Giddings' and Berg's practical demonstrations of the relation of the galls in the red cedars to the apple rust which played an important role in settling the law suits against the State for cutting the red cedars in proximity to apple orchards. Many worthy citizens in the Valley considered red cedars to be of more aesthetic value than the apple orchards. Berg also worked on rust resistance in the red cedar. He found an immune red cedar at Priest's Field in Jefferson County from which propagations by cuttings and grafts were made and distributed in other States, where it is known as "Berg's rust-resistant red cedar" (Anthony Berg. A Rust Resistant Cedar. *Phytopath.* 30: 876-878. 1940).

The chestnut blight was found in West Virginia about 1910, and investigations were begun in 1912 by A. B. Brooks, Forest Pathologist, employed jointly by the U. S. Department of Agriculture and the West Virginia Agricultural Experiment Station, with Giddings cooperating. Several acres of forest land were acquired by the State near Great Cacapon, on which a laboratory was established for the study of the blight. One bulletin was published by Giddings. "Chestnut Bark Disease" (West Virginia Agr. Expt. Sta. Bull. 137. 1912).

"Collar blight" became recognized as an important disease of Grimes and certain other apple varieties early in the development of the apple industry in the Shenandoah Valley. Giddings carried on a rather intensive study on the control of this disease through surgical methods and inarching which saved many trees which would have died without such treatment ("The Collar Blight of Apple Trees" by N. J. Giddings, West Virginia Dept. of Agr. Rept. 29: 15. 1913).

In 1909 and 1910 there were many reports of a serious disease of tomatoes in southern West Virginia. This problem was assigned to Berg, who proved that a strain of *Phytophthora infestans* was the cause. Berg's careful technique enabled him to culture the organism, prove its pathogenicity and establish its close relationship with the strain causing late blight of potatoes. The results were published under the title, "Tomato Late Blight and Its Relationship to Late Blight of Potato" (Giddings, N. J. and Anthony Berg, West Virginia Agr. Expt. Sta. Bull. 205. 1926; also *Phytopath.* 9: 209-211. 1919).

In 1910, Mr. D. Gold Miller, a prominent orchardist in Berkeley County, sprayed a block of York Imperial apples with Atomic sulfur, with the result that those trees were practically free from rust. This set Giddings to work on a comparison of dusting vs. spraying which continued for several years; during which time several States cooperated in comparative tests.

Three publications from the West Virginia Station resulted from this project (Giddings, N. J. Orchard Spraying versus Dusting. West Virginia Agr. Expt. Sta. Bull. 167. 1918; Giddings, N. J. Orchard Dusting versus Spraying. *Jour. Econ. Ent.* 14: 225-231. 1921; Giddings, N. J., Anthony Berg and E. E. Sherwood. Dusting and Spraying in the Apple Orchard. West Virginia Agr. Expt. Sta. Bull. 209. 1927.)

The cooperative study with other States and Ontario was reported and published under the title "Cooperative Dusting and Spraying Experiments in 1921", and edited by C. R. Orton as a cooperative venture under the auspices of the Crop Protection Institute. (*C.P.I. Digest.* 1: No. 2, 1-30, 1922). It was shown that dust fungicides were nearly as effective as sprays on peaches but not as effective as sprays on apple diseases, although dusts gave good commercial control of frog-eye leaf spot.

With the acquisition, in 1916, of farm land as a gift to the Agricultural Experiment Station from Monongalia County, the Department of Plant Pathology was assigned a tract adjacent to the Horticultural Farm. An experimental planting of apple trees for rust studies brought prompt and urgent protests which resulted in moving to a tract back of the Agronomy Farm. This area was developed as a pathologium which was actively used for experimental work until after Dr. Giddings resigned in 1929. Since then, it has been used primarily for the walnut canker and chestnut blight projects.

Potato Wart was discovered in Pennsylvania in 1918 and a year later in two localities in West Virginia in Grant and Tucker Counties, at relatively high altitudes. The scare caused by these discoveries persisted for several years, and quarantine regulations invoked at the time are still in force though the disease has not recurred for several years.

Oglebay Hall was erected in 1918, and Plant Pathology moved to the top floor of the new building along with Botany. This was a welcome change of quarters which was further improved in 1927 when Botany moved to Science Hall and Plant Pathology was given one office and the laboratory vacated by that department. Greenhouse space, which had always been a problem, was partially solved by the erection of a new greenhouse in 1920 for use by Botany and Plant Pathology.

The demand for plant pathological work was increasing and, in July 1, 1920, E. C. Sherwood, who had just completed work for the Master's degree at the University of Wisconsin, was

appointed Extension Plant Pathologist, and Assistant Plant Pathologist in the Experiment Station. In July, 1926, he gave up his work in the Experiment Station and assumed half-time duties in regulatory work with the State Department of Agriculture. This arrangement was continued until his retirement in 1949. Sherwood's methodical approach to the practical control of orchard diseases and insect pests remains a standard of excellence as attested by the fruit growers of West Virginia and neighboring States. The annual control schedule published by Sherwood from the years 1926 to the present is a standard reference for the Shenandoah fruit-belt orchardists. Current issues appear under the title "Orchard Spraying Guide". Sherwood also published numerous special Extension circulars covering the diseases and insect pests of all cultivated crops.

An important addition to the staff was made in 1922 when L. H. Leonian, fresh from his doctorate work in Kauffman's laboratory at Michigan, was appointed as Assistant Plant Pathologist. His enthusiasm, training, productivity, and *esprit de corps* were most valuable adjuncts in the further development of the department. His scientific contributions were numerous and covered a wide field. His notable early contributions dealt with variability in the genera *Phytophthora* and *Fusarium*. For a time, he became interested in the fungi causing human diseases, but later concentrated his efforts in a study of the physiology of fungi with V. G. Lilly, a field which proved of special interest to him and in which he made notable progress. He became Professor of Mycology in 1936 and during the war years taught general bacteriology very successfully. Unfortunately, his career was untimely terminated by cancer which caused his death June 7, 1945.

Late in the 1920's, reports of a new apple disease came in from several sections of the State. The disease resembled one which occurred in Arkansas and had been described by Hewitt of the Arkansas Agricultural Experiment Station as "measles." Mr. Berg was assigned to its study, and field work was initiated in Putnam County near Winfield, in Chester County, and in Hampshire and Mineral Counties. The disease also became serious in Illinois, and specimens were received from several other States. Berg's studies soon led to the conclusion that more than one disease was involved in the "measles complex". He succeeded in isolating a *Helminthosporium* from the diseased trees at Winfield, which proved actively pathogenic. He named this disease "black pox" and described the pathogen under the name *H. papulosum*.

Giddings obtained a leave of absence in 1916-17 for graduate study at the University of Wisconsin, from which he obtained the doctorate in 1918. He remained head of the department until June 30, 1929, when he resigned to accept a position as Senior Pathologist in the U. S. Department of Agriculture. He has been stationed at Riverside, California, since that date.

The position thus vacated was filled by C. R. Orton, a graduate of the University of Vermont, with a Master's degree from Purdue University and his doctorate from Columbia University. At that time, Orton was engaged in research on seed disinfectants at the Boyce Thompson Institute, work financed at first by The Bayer Company, Inc., and later by the Bayer-Semesan Company. He had served previously for 12 years as Plant Pathologist at the Pennsylvania Agricultural Experiment Station and as Professor of Plant Pathology in the Pennsylvania State College.

The year 1930 may be termed the beginning of the period of graduate work in the department. Two graduate assistants were appointed that year--Joseph Myers Ashcroft and Bailey Sleeth, both graduates of West Virginia University, the latter having already taken his Master's degree at the University. Sleeth completed his work and received his doctorate in June 1932. His thesis was published in Bulletin No. 257 in 1934 under the title "*Fusarium niveum*, the Cause of Watermelon Wilt". Ashcroft completed his Master's degree in June 1931 and his Ph.D. in June 1933. His thesis "European Canker of Black Walnut and Other Hardwoods" was published as Bulletin No. 261, 1934. Up to the present time, 20 M.S. and 20 Ph.D. degrees have been earned in the Department.

Financial stringencies hit the State in 1933 when the Legislature cut the University appropriation heavily. President Turner advocated cutting overhead administrative expenses by merging related departments. An executive order was issued to Orton and Dr. P. D. Strausbaugh to study the possibility of merging all biological work excepting medicine, in a Department of Biology. A detailed report was made to the President, suggesting that Botany, Zoology, Bacteriology, Physiology, Forestry, and Plant Pathology could be organized in one department and all be housed, so far as possible, in Science Hall. This suggestion was approved by the Board of Governors and Orton was appointed head of a new Department of Biology to be administered in the College of Agriculture and Home Economics.

This was a major operation which involved moving Plant Pathology into the basement of Science Hall which, up to that time, had been used chiefly for storage. The move was made and the entire curriculum was revised. The transfer of Botany and Zoology from the College of Arts

and Sciences into a department administered in the College of Agriculture was considered by some staff members to be a serious mistake. Administrative and personnel difficulties eventually led to the dissolution of the Department of Biology in 1936 during the residency of Dr. Boucher. The Department of Plant Pathology emerged as a Department of Plant Pathology and Forestry, with Bacteriology included. Botany and Zoology were returned as a merged department to the College of Arts and Sciences. In the separation, Genevieve Clulo was transferred to the Department of Plant Pathology.

In 1938 Forestry was made a new division of the college and bacteriology was officially recognized in the reorganized Department of Plant Pathology and Bacteriology. In this year, Orton was appointed Dean and Director, and J. G. Leach, a graduate of the University of Tennessee with a doctorate from Minnesota, and at that time Professor of Plant Pathology at Minnesota, was appointed Head of the Department. Eldor A. Marten (Ph.D. Wisconsin) was Associate Professor of Bacteriology from 1936 to 1941. He did research and published papers on soil microbiology, ring rot of potatoes, and factors influencing the toxicity of cuprous oxide. Marten was succeeded by Dr. A. R. Colmer (Ph.D. Wisconsin) who resigned in 1947. While at West Virginia, Dr. Colmer did research and published papers on the pasteurization of walnut meats and on the microbiology of acid mine waters. The work on mine water bacteria was revolutionary in nature and has contributed much to the important problem of stream pollution.

Dr. Colmer was succeeded in 1947 by Dr. H. A. Wilson (Ph.D., Iowa State College), and in 1948 an additional instructor in Bacteriology was added to the Department by the appointment of Mary Alice Ryan (M.S., West Virginia University).

Three members of the Department of Plant Pathology and Bacteriology have died in active service. Lawson M. Hill who with C. R. Orton made pioneer studies in purple-top wilt of potatoes, was appointed assistant in Plant Pathology in 1937 and died in 1939 while on leave of absence at the University of Arizona. Dr. Leonian, Professor of Mycology, who joined the staff in 1922, died in 1945 after 23 years of productive research in the physiology of the fungi. Anthony Berg, who joined the staff in 1913, died suddenly from a heart attack in 1947 after 34 years of service. He was a member of the department for a longer period of time than any other person.

PRESENT

J. G. Leach

The Department of Plant Pathology and Bacteriology is now in the College of Agriculture, Forestry and Home Economics. Its scope of responsibility includes both teaching and experiment station research in the fields of Plant Pathology, Mycology, and Agricultural Bacteriology. The Department is not responsible for teaching or research in general botany. It is limited to and includes all phases of microbiology with the exception of medical bacteriology which is handled by the Medical School. The work of the Department is about equally divided between teaching and research. All members of the staff, with one exception, do some teaching, but, with the exception of the bacteriologists who have a large enrollment in general bacteriology, the teaching loads are not excessively heavy, and the subjects taught are mostly at the graduate level.

The present staff members are listed below, with a brief statement of training experience and responsibilities.

- J. G. Leach, Ph.D., Minnesota, 1922 (formerly professor of Plant Pathology, University of Minnesota). Department Head since 1938. Responsible for administration of department, research work in field of forage and pasture crops, miscellaneous diseases, and insect transmission of plant diseases. Participates in teaching Elementary Plant Pathology, Advanced Plant Pathology and Insect Transmission of Plant Diseases.
- C. F. Taylor, Ph.D., Cornell 1936. Professor of Plant Pathology in charge of teaching and research in Diseases of Fruits. Came to West Virginia in 1938. Participates in teaching Elementary Plant Pathology and teaches a course in the Application of Fungicides, Insecticides and Fumigants, and one in Diseases of Fruits.
- R. P. True, Ph.D., University of Pennsylvania 1934. Associate Professor of Plant Pathology (formerly Associate Plant Pathologist, Office of Forest Pathology, U. S. Department of Agriculture). Responsible for teaching and research in the field of forest pathology. Teaches a class in Forest Pathology and a class in Diseases of Ornamental Plants.
- M. E. Gallegly, Ph.D., Wisconsin 1949. Assistant Professor of Plant Pathology. Responsible for research on diseases of potatoes and vegetable crops. Teaches a class in Diseases of Vegetable Crops and participates in teaching a class in Advanced Plant Pathology.

- C. R. Orton, Ph.D., Columbia 1924, Professor of Plant Pathology. (Formerly of Purdue, Penn State, Head of Department of Plant Pathology, West Virginia 1929-1938, and Dean of the College of Agriculture and Director of the Agriculture Experiment Station, West Virginia University 1938-1949). Research on *Phyllachora* and on internal bark necrosis of apple. Teaches a course in Pathological Plant Anatomy.
- Genevieve Clulo Berg, A.M., West Virginia 1929. Associate Plant Pathologist. Responsible for research on internal bark necrosis of apple and on pathological anatomy of plants.
- C. F. Bishop, Ph.D., West Virginia University 1948. Extension Plant Pathologist and Entomologist. Responsible for Extension work in Plant Pathology and Entomology for all crops except orchard fruits.
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- At the present time, there is one vacancy in the Department, caused by the retirement of E. C. Sherwood who was Extension Plant Pathologist for diseases of orchard fruits.
- H. A. Wilson, Ph.D., Iowa Agricultural College 1937. Associate Professor of Bacteriology. In charge of teaching and research in general and agricultural bacteriology. Teaches courses in general bacteriology, soil microbiology, water analysis, and special topics in advanced bacteriology. Engaged in research on problems of soil bacteriology and bacteriology of mine seepage waters.
- Mary Alice Ryan, M.S., West Virginia University 1948. Instructor in Bacteriology. (On leave, 1949-50, working for doctorate at Penn State). Field of interest - Dairy and Food Bacteriology.
- H. L. Barnett, Ph.D., Michigan State 1937. Professor of Mycology, teaching and research in Mycology. Teaches two courses in Mycology and participates in teaching a course in the Physiology of the Fungi. (Came to West Virginia in 1945 from University of Iowa).
- V. G. Lilly, Ph.D., in Chemistry, West Virginia University 1932. Professor of Physiology. Teaching and Research in the field of Physiology of the fungi. Participates in teaching a course in the Physiology of the Fungi.

In addition to the above full-time staff, there are six half-time graduate assistants in the Department. Three in plant pathology, two in physiology of fungi, and one in bacteriology.

There are seven graduate students majoring in the department, the limit of our laboratory facilities until we move into the new building.

The Department, at present, is housed in Science Hall, one of the three oldest buildings on the campus, with very inadequate space, but is scheduled to move into modern quarters in the new Biology Building now under construction, slated to be completed by September 1950. The new quarters will be modern in all respects with adequate space for teaching and research, including room for 12 to 15 graduate students. A new greenhouse for the Department is planned in connection with the new building. Sufficient greenhouse space for our present needs are available, but the houses are not modern and are not conveniently located to the new building.

Three experimental farms are available for research in field, vegetable, and forage crops. Two are within two miles of the campus, one 18 miles away. Orchard fruit research is done chiefly at University Farm, a substation located at Kearneysville in the Eastern Panhandle. For forest pathology, there is available a State-owned forest of 8,000 acres about 15 miles from the campus and State-owned forest lands in many other locations, including a University Forestry Camp in Greenbrier County. Forest Pathology work is done in close cooperation with the Forestry School which is engaged in a comprehensive Experiment Station program.

Some of the principal contributions of the Department in recent years are as follows:

1. The extensive work on the physiology of the fungi started by the late Dr. L. H. Leonian, ably assisted by Dr. Lilly, and continued since Dr. Leonian's death by Dr. Barnett and Dr. Lilly, who are now writing a text book on the Physiology of the Fungi, to be published soon by McGraw-Hill Book Company. In addition to their regular experiment station work, Drs. Lilly and Barnett are directing an extensive research program on the physiology of fungi under a contract with the U. S. Army.

2. The proof of the nature and cause of the apple disease complex known as apple measles separating the parasitic disease "black pox" from the non-parasitic "internal bark necrosis" which has been shown to be caused by manganese toxicity.

3. The experimental work on control of cherry leaf spot and the demonstration of the severe cumulative injury caused by this disease. The revised spray program based on this research has saved the cherry industry of the State.

4. Demonstration that acidity of mine seepage water is due to bacterial oxidation of sulfur rather than simple chemical oxidation as generally believed.

5. Demonstration that the red precipitation of ferric hydroxide in mine seepage water is due to, and dependent upon, bacterial action.

6. The "Dealers Contact" extension program through which the control of diseases and insect pests of the home garden was greatly facilitated. For the first time in the history of the State, the insecticides and fungicides recommended by the University are available in retail stores in practically every town in the State.

7. Demonstration of the nature, cause and method of spread of purple-top wilt of potatoes and that it could be successfully combatted by controlling the aster leaf hopper with DDT. Since the use of DDT on potatoes has become a general practice, purple-top wilt has ceased to be a disease of economic importance in West Virginia, where it was once among the most destructive diseases affecting the potato.

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